Go-Lab

Global Online Science Labs for Inquiry Learning at School

Collaborative Project in European Union's Seventh Framework Programme

Grant Agreement no. 317601

Deliverable D8.4

Integrated validation and evaluation report and recommendations – complete version

Editors	Evita Tasiopoulou, Ton de Jong, Enrique Martin
Date	26-10-2016
Dissemination Level	Internal
Status	Final

The Go-Lab Consortium

Beneficiary Number	Beneficiary name	Beneficiary short name	Country
1	University Twente	UT	The Netherlands
2	Ellinogermaniki Agogi Scholi Panagea Savva AE	EA	Greece
3	Ecole Polytechnique Fédérale de Lausanne	EPFL	Switzerland
4	EUN Partnership AISBL	EUN	Belgium
5	IMC AG	IMC	Germany
6	Universidad Nacional de Educación a Distancia	UNED	Spain
7	University of Leicester	ULEIC	United Kingdom
8	University of Cyprus	UCY	Cyprus
9	Universität Duisburg-Essen	UDE	Germany
10	Centre for Research and Technology Hellas	CERTH	Greece
11	Universidad de la Iglesia de Deusto	UDEUSTO	Spain
12	Fachhochschule Kärnten – Gemeinnützige Privatstiftung	CUAS	Austria
13	Tartu Ulikool	UTE	Estonia
14	European Organization for Nuclear Research	CERN	Switzerland
15	European Space Agency	ESA	France
16	University of Glamorgan	UoG	United Kingdom
17	Institute of Accelerating Systems and Applications	IASA	Greece
18	Núcleo Interactivo de Astronomia	NUCLIO	Portugal

Contributors

Name	Institution
Ton de Jong	UT
Siswa van Riesen	UT
Ellen Wassink-Kamp	UT
Henny Leemkuil	UT
Mario Mäeots	UTE
Margus Pedaste	UTE
Leo Siiman	UTE
Zacharias Zacharia	UCY
Tasos Hovardas	UCY
Nikoletta Xenofontos	UCY
Anna Fiakkou	UCY
Evita Tasiopoulou	EUN
Agueda Gras	EUN
Enrique Martin	EUN
Teodora Ioan	EUN
Fani Stylianidou	EA
Olga Dziabenko	UDEUSTO
Rob Edlin-White	ULEIC
Effie Law	ULEIC

Legal Notices

Executive Summary

The main aims of this deliverable are to provide a full analysis of the evaluation data that has been collected in the course of project's final implementation year along with a set of recommendations targeting project's main audiences i.e. teachers and schools.

In Section 1, we are presenting a set of recommendations for the design of Go-Lab learning environments (ILSs) and for implementing and introducing Go-Lab in class and in school organisations. The section starts by listing teaching situations that teachers may have encountered during their implementations. The provided recommendations, which follow a homogeneous structure, are basically responding to the presented situations addressing, at first, teachers and advising them on the creation of ILSs but also targeting schools and advising them on the adaptation and use of Go-Lab. Attention is also given to the scalability of the project so specific recommendations are provided in this issue.

Section 2, presents a collection of Annexes which include all evaluation data that has been collected by WP8 including student studies, large-scale evaluation and case studies. Starting from the students' focused studies, the methodology results of the 2 common and the individual studies are presented. Studies are presented by using a common structure which starts with the discussion of the issue to be investigated, continues with the description of the selected experiments and concludes with the collected data and observations. The results from the large-scale evaluation for both teachers and students are also provided. These sub sections start by presenting the evaluation instruments used, the data sample that has been acquired and proceeding to the analysis of each of the respective questions. Complete and light case studies are also presented. Complete case studies which included class observations, interviews with teachers and headmasters have taken place in 6 countries while light case studies, which were based on short interviews with pilot teachers, have covered 9 countries.

Table of Contents

1 Introduction

This document presents a set of recommendations for the design of Go-Lab learning environments (ILSs) and for implementing and introducing Go-Lab in a class and in school organisations. The recommendations in this document are primarily based on the validation and evaluation activities conducted in Go-Lab's WP8. These evaluation and validation activities comprised:

- A large set of studies conducted by the Go-Lab consortium in which specific tools (apps) as offered by Go-Lab were assessed on their usability and learning effectiveness. These studies were reported in Go-Lab deliverable D8.3 and most of the studies are now submitted as manuscripts to scientific journals. In the appendices of the current deliverable (D8.4) one of the studies that was reported in D8.3 is again included but now with a set of additional analysis (see Annex 2) and an additional study that was still ongoing at the time of submitting D8.4 is also included (see Annex 2).
- A large scale study on the effects of the use of a series of Go-Lab ILSs in comparison with traditional instruction. This study was conducted as a "concurrent replication" meaning that the experiment was performed in a similar way in a number of different countries (see Annex 2).
- Two large scale questionnaire studies, one for teachers and one for students in which information related to the impact of Go-Lab in both groups has been collected along with useful feedback on the actual use, frequency and usability of the different parts of the system, have been carried out and analysed (see Annexes 3-4).
- A set of case studies with selected teachers, inquiring these teachers about their Go-Lab experiences as an author of ILSs and as users of ILSs in their classrooms (see Annex 5).

In conducting these evaluation and validation activities Go-Lab project members have been in close contact with teachers and with learners when being present at many Go-Lab sessions in the actual classroom. In these contacts many informal but still very valuable impressions were gathered and these were used to complement the recommendations that could be formulated on the basis of the formal validation and evaluation activities.

The recommendations are grouped into three main categories: recommendations for teachers aiming to the effective implementation and creation of ILSs, recommendations on how to support teachers' work and involvement and scalability recommendations (enhancement and outreach of the project). Under each category we present recommendations that focus on how to design ILSs and include lessons learned from student interactions and outcomes from learning with ILSs, so these recommendations focus on how to optimize ILSs for students. These recommendations mainly come from the WP8 experimental studies supplemented with questionnaire data and informal observations. The second sub category of recommendations concern ways to support the work of teachers in designing and implementing ILSs. The questionnaire data and the case studies are the main input for this set of recommendations. The third, and final, sub category of recommendations focuses on how to include Go-Lab ILSs into a curriculum or school organizational framework so that students and teachers experience it as part of the larger school approach. Following these recommendations lays the basis for Go-Lab as a scalable product. Again, these recommendations are based on questionnaire data and case studies. Each recommendation is presented using a format in which the issue that is being addressed is mentioned first, then the recommendation itself is given, and finally the data that have led to the recommendation (coming from the formal evaluation and validation activities or from the informal observations) is reported.

2 Prototypical teaching situations

The following teaching situations exemplify different possible scenarios that may be encountered by teachers when implementing the Go-Lab educational innovations within their lessons. All of the issues arising are analysed from these situations are presented together with possible solutions (recommendations) and background analysis in section 1.3.

Situation 1

Many teachers state that the inquiry learning approach and the use of ICT in their classroom is new for them (this is also applicable to the students). Teachers are not used to constructing knowledge based on exploration and experimentation and therefore they find it difficult to start with an ILS that covers the whole inquiry circle. Furthermore, with inquiry learning there is not just one 'correct' answer and there are many routes a student can take towards an answer. For many students, this is a confusing process. Besides getting used to the inquiry approach, students also have to learn how to use the labs and apps that are implemented in ILS's to support the students.

This situation may be exemplified as follows:

"A "traditional teacher" used to giving direct instructions to his students and doing hands-on-experiments in the school lab, wants to change his teaching practice to inquiry learning and the use of virtual and remote labs. This teacher, decides to start by implementing in his classroom one of the ILSs that was developed by another teacher and that is available on golabz.eu."

A number of issues might arise in connection to the situation above expressed. "Traditional" science teachers, and especially those in countries where ongoing student assessment is a high requirement, sometimes bring forward rather idiosyncratic models of pedagogy into their implementation of Go-Lab and thus, don't get to fully develop the Go-Lab experience.

This is also closely related to the fact that for many students the inquiry approach is new. In traditional education there is usually one 'single' correct answer to the problem posed. Actually, in many cases students, only learn one procedure to arrive to this correct answer. When following the procedure, they simply arrive at the correct answer and know they have done well. With inquiry learning there is not just one 'correct' answer and there are multiple paths a student can take towards the final answer. For many students, this swift might be very confusing at the beginning and proper guidance is thus needed. Thus, teachers should be aware that whereas knowledge effects are immediate, inquiry skills effects take a longer time.

On the other hand, from the technical side, students often find it difficult to start with an ILS that covers the whole inquiry circle, not only because they are not used to inquiry learning, but also because they might not be used to this kind of on-line environments. Even though most of the Go-Lab tools are quite intuitive, students, especially at the beginning, need explanations on how to work with them. Many teachers might choose to give a quick walk-through of an ILS at the beginning of class, explaining all the different tools and possibilities. Additionally, each tool has a help function and most ILSs include a written instruction. But despite all these efforts, many students may still have trouble working with some of these tools and if there are many questions of these type of issues from the beginning, the normal development of the lesson could be disrupted. In this regard, Go-Lab offers a broad range of effective tools to help students with various tasks. Students will have to get to know each tool teachers include and it will take them some time to figure out how to work with them. Including too many tools might end up being counterproductive. All the issues mentioned have to be taken into consideration together with the scenarios of the use of technologies per se, sometimes simple things such as the use of audio, video inside a classroom might lead to distraction, if the activity and materials are not organized and properly set.

Situation 2

Working with Inquiry Learning Spaces gives students great control over their own learning processes, but at the same time, it demands a lot of their self-regulations skills. Students (especially the younger ones) need more instructions (guidance) than teachers envision. Things that might seem obvious for a (more) experienced user (pressing a button or tab, clicking on an item to change its appearance or characteristics) are often not clear to new users. This is especially the case if you consider the following: First of all, many labs and some apps don't contain instructions on their usage, and when these instructions are there, students often don't read them. Second, many students experience problems when they go through the phases of the inquiry cycle. They have difficulties in formulating research questions and hypotheses, in designing experiments and in interpreting the data they have collected. Third, students sometimes have misconceptions or gaps in their prior knowledge which have a great impact on the learning process.

This situation may be exemplified as follows:

"A teacher has used several ILSs and experienced that some students can work for themselves very well but that others keep asking questions and need more guidance. S/he wants to adapt the ILSs found on golabz.eu to his/her own needs and to those of his/her students."

Is relation to the above situation, we should also consider all the possible issues that might come up when teachers are working in their ILS for classes including "multiple variables" and of course, the curriculum itself. Many students need more instructions than teachers could initially expect. Things that might seem obvious for more experienced users are often not that clear to new users. This is the reason why every single detail counts and might become an issue if not taken into consideration. Matters such as the length of ILS are relevant, requiring students to scroll up and down and move backwards and forwards between tabs to complete the lesson. We have to notice that ILSs include by default five phases. In some cases, the content per phase can become very extensive. If a phase contains too much information in the form of text, tools and videos students may easily go unnoticed and the risk that they accidently skip parts is also considerable.

Another challenge might be establishing the line which determines how independent we expect students work to be, for instance, Tools (apps) can be configured to provide 'more or less' help, but what is the best way to do this to give students sufficient support together without undermining the necessary challenge? Working with Inquiry Learning Spaces gives students great control over their own learning processes, but at the same time demands a lot of their self-regulations skills. Depending on the design of the ILS, students might have to decide for themselves what they know and what they want to find out, determine whether or not they have done enough experiments to formulate a conclusion or judge when they are ready to proceed to the next phase or if in the contrary, they need to go back to the previous one. This could become struggle for students and may cause cognitive overload.

A major issue when adapting an ILS, is being able to identify and consider students' knowledge. Misconceptions and gaps in students' knowledge can greatly impact their learning. If the gap is too big, students will not be able to relate the content of the ILS to their prior knowledge. This means that it might be difficult for them to give meaning to the things they are doing within the ILS and end up losing interest.

Finally, other typical obstacles that students may have to face such as estimating the appropriate time to be spend on each app (it might depend on the design too), the formulation of hypothesis or research questions, the design of their own experiments or even when analysing and understanding the results. Hence, not being able to reach conclusions or making connections with their experience and the everyday life.

Situation 3

Teachers looking for alternative learning scenarios sometimes opt for blended learning sessions in which they combine an ILS with real lab activities, or combine virtual labs with real labs. Others choose a group work scenario for instance based on the Jigsaw approach, in which 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. Other alternative scenarios put the focus on critical thinking by asking students to critique or find mistakes in the work reported by others.

This situation may be exemplified as follows:

"A teacher uses ILSs often and is able to adjust them to his/her own wishes. But s/he is afraid that the students will get bored throughout the year because the basic scenario of the lessons is the same. S/he is searching for alternative learning scenarios."

Situation 2 focussed on the issues confronted by teachers when adapting ILSs to their (and students) needs. In this case, situation 3 spotlights those issues connected to the sustained used of Go-Lab tools. Many times, ILSs are perceived by teachers as a vehicle for supporting online labs only. Nevertheless, an ILS can be effectively used for designing and delivering lessons involving a combination of real labs and online labs, or even for lessons involving only real labs. In this regard, options become infinite and this might have negative consequences (if not dealt properly).it goes without saying that most of the issues arising from this situation are resultant (and depending) of the different teaching scenarios. From the classical environment were students appear not to be engaged by traditional teaching anymore (especially when it comes to individual working) and most of the times, technology in the classroom is not used adequately to support student collaboration, to a ICT enhanced classrooms, where it seems that as soon as students are using a computer (or other interactive device) they are already expecting a high degree of interaction. All of the above together with the fact, that when using ILSs in the classroom context, different students work at different paces (benefitting from different levels of intellectual challenge); and what's more, that critical thinking is not directly related to specific subjects, makes the very least an interesting (not to say complex) “cocktail” for the teacher, indeed, when considering mid- term and long-term use of the ILSs.

The composition of remote and virtual experiments to teach topics in science allows employing two concepts: first, understanding the pattern of a physical process through the virtual experiment and second, exploring a real mechanism in nature using remote experiments. With this kind of help, a student can understand the whole scientific picture while simultaneously experimenting without physical and time limitations. The challenge is in this sense, for teachers to be able to profit of this advantages, while combining them and planning in advance for a proper and sustained of the Go-Lab tools.

Situation 4

When teachers are using ILSs, they realise that their role is changing from an instructor to facilitator/supporter. To play this role in a meaningful way, they feel the need to monitor the learning process of the students. On the golabz.eu site several apps are available to support teachers in performing this role. There are apps that give them an overview of the time spend by the students in the different phases, or of the input given by students or that give the opportunity to give individualised feedback.

This situation may be exemplified as follows:

“A teacher uses ILSs often but s/he wants to know more about what the students actually are doing during the lessons. Now s/he only gets their report at the end of series of lessons, but s/he would like to monitor the learning process of the learners.”

Keeping track of the work of student can certainly become a huge challenge, especially when thinking of ILS within the use of virtual and remote labs. It is important for the teacher to be able to select the correct amount and type of tools in order to focus them and enact on-the-fly assessment. Reflection is an important strategy for students to improve their learning and derive meaningful insights from their experiences. However, reflection does not usually occur spontaneously since most students are not capable of reflecting on their learning without guidance. This is when an adequate monitoring of students become crucial, enabling teachers to intervene whenever considered necessary.

Open-ended inquiry may also present a number of issues connected to the monitoring of students. Since it generally takes longer than structured and guided inquiry, this approach might be appropriate for students already comfortable with completing inquiry activities. On the other hand, novice learners, might need ILSs to be adapted in order to fit the time constraints of a classroom lesson. To determine which parts of an ILS may take too long for beginners, it becomes indispensable for a teacher to be able to properly track students work and hence, use the Go-Lab learning analytics apps to monitor progress, and the adequate length of section the different sections and activities.

3 Recommendations to teachers on the creation of effective ILSs

The following recommendations are structured within the rationale hereby defined:

- Inquiry learning
- Characteristics of a (good) ILS
  - Context
  - Prior knowledge activation
  - tools and videos
  - experimenting
  - reflection
- Configuring apps to level of experience or prior knowledge
- Scenarios of use
  - Blended learning
  - Cooperative learning
- Monitoring

3.1 Inquiry learning

Gradually increase complexity of the inquiry tasks

Issue: Students often find it difficult to start with an ILS that covers the whole inquiry circle because they are not used to inquiry learning.

Recommendation: Make sure that students get a good introduction in the inquiry approach and the tools to be used. If you plan to do Lab work and inquiry tasks regularly, be sure there is a gradual increase in complexity. Start of with cookbook like experiments and end with real inquiry. For instance, you could start with inquiry tasks in which you give the students (parts of) the hypothesis/research question or limit the set of options. In this way the students can gradually get used to the inquiry approach.

Background & analysis: Many teachers state that they themselves but also their students are not used to inquiry learning. They are used to doing assignments/experiments in the school lab with real equipment but in these cases the students usually are told what they have to do. They just have to observe what happens and make notes. In that case the students only perform some of the steps that are in the full inquiry circle (Figure 1). Gradually increasing the number of steps in the inquiry process can help students getting acquainted with inquiry learning

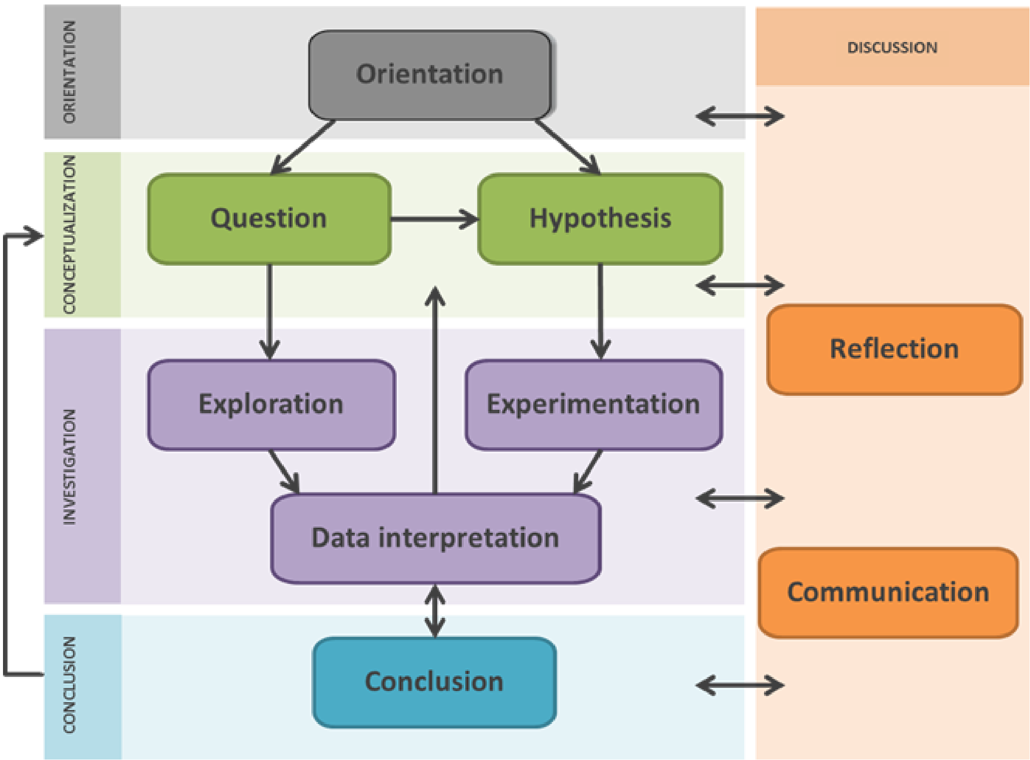


Figure 1. Full inquiry cycle.

You could also work together with colleagues to set up a set/sequence of inquiry spaces on different topics. This allows students to get acquainted with inquiry learning and to gain inquiry skills; developing skills takes time and practice (common study -yet to be analysed- for teachers).

Make students aware of the fact that there is no ‘correct’ answer

Issue: For many students the inquiry approach is new. In traditional education there is usually one good answer to a question. Often students also learn only one procedure to arrive at this correct answer. When they follow the procedure, and arrive at the correct answer, they know they have done well. With inquiry learning there is not just one ‘correct’ answer and there are many routes a student can take towards an answer. For many students, this is confusing.

Recommendations: Students need to understand that there is not one way to go about an investigation. It is important to explain this to them extensively. Make clear that it doesn't matter whether their hypothesis is true or false, if it is well formulated. Explain that there is not a fixed number of experiments that they have to carry out, as long as they do enough to validate their hypothesis. Explain that there is not one way to design a good experiment, as long as they make sure the experimental design is sound. Students really have to change their way of thinking.

In Go-Lab students can practice with this new way of learning and become more confident to judge for themselves if an answer is good or correct or not, without relying on the teacher. The conclusion tool will help this process. In the conclusion tool students compare the evidence they have gathered with their question or hypothesis. They are asked to argue why this evidence confirms or disconfirms their hypothesis and using the confidence meter they indicate how strong they believe their evidence is.

Background & analysis: Teachers indicated that they get a lot of questions from students like: 'am I doing this correctly,' 'have I done enough experiments' and 'is this the correct answer'. Students are uncomfortable at first, because they are so focused on producing a correct answer. They need some time to change their thinking and get used to this new type of learning, which may take some time.

Give students clear instructions

Issue: Students (especially the younger ones) need more instructions (guidance) than you would expect. Things that might seem obvious for a (more) experienced user (pressing a button or tab, clicking on an item to change its appearance or characteristics) are often not clear to new users.

Recommendation: Put in the text explicit statements about what students are expected to do. For instance: "Now you have reached the end of the Orientation phase, press the tab "Conceptualisation" to go to the next phase" or "Click on the tube when you want to change the characteristics of the fluent or from the ball in the tube. Then use the sliders in the top of the window to actually change the characteristics."

Background & analysis: Many of the labs and apps listed in the Go-Lab repository (for instance all the Phet labs) don't contain instructions for use. This means that users have to find out for themselves which elements can be manipulated and what they should do and in which order. This leads to trial and error behaviour and sometimes to frustration. Several teachers have reported that students need more guidance in using the labs and apps. A teacher answered to one of the questions in a Practice reflection workshop "Especially for young students more support and guidance from teachers would be helpful to make the audience understand everything correctly and to make sure their attention is focused". Some teachers decided to present the lab/app by making use of the electronic whiteboard before students started using the ILS individually.

Two small examples of situations that need additional information. In the Electrical circuits lab (see Figure 2) you can use an Ampere meter. To do this you have to drag the small circle with the "A" to the circuit. Students often try to move the large circle with the "A". It is possible to move this but as soon as you release the mouse it will return to its original place at the right side of the screen.

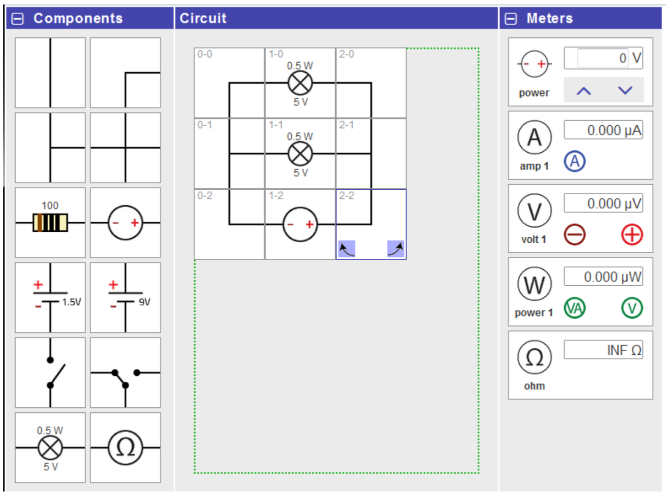


Figure 2. Electrical circuit lab (Ambere meter).

Another example. In the Splash lab you can change the content of the six tubes that are displayed but to be able to do this you first have to select the tube by clicking on it.

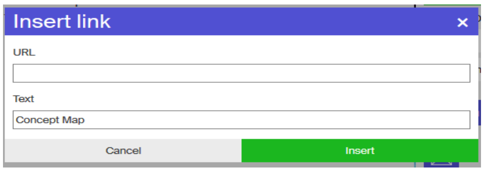


Figure 3. Electrical circuit lab (http://go-lab.gw.utwente.nl/production/splash/build/splash.html).

The Go-Lab authoring platform offers the opportunity to give additional information to the students by means of Hints. The text of the hint is only displayed when student clicks on it. To do this embed a text document in a phase and then press on the upper right corner. A menu will be displayed which contains the option “Set as hint” (see Figure 4).

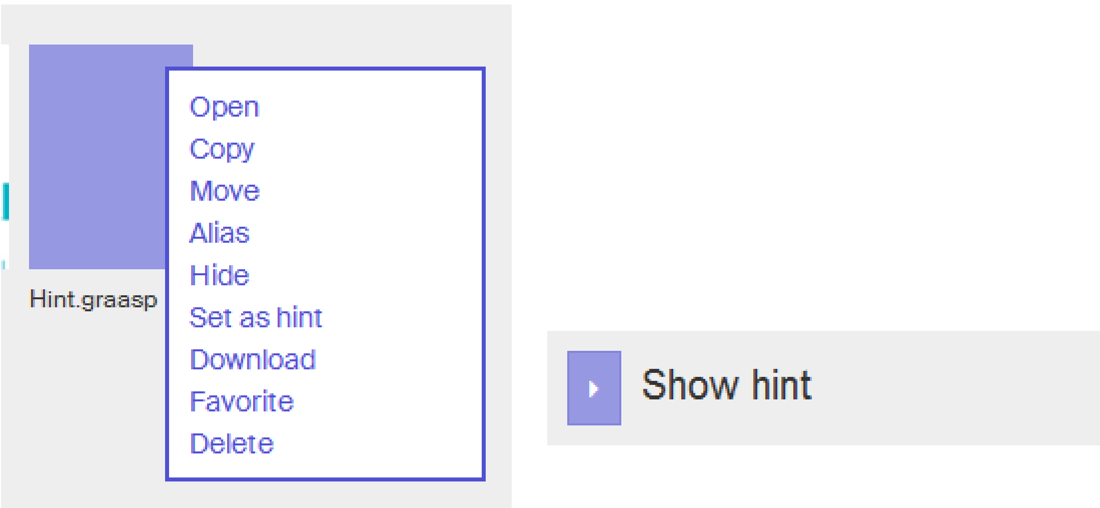


Figure 4.

For some of the apps short instructional videos are available that give instructions on their usage (http://www.golabz.eu/videos). You could implement these in your ILS. However, when you embed them in the text students will have to scroll a lot. An alternative solution is to put a link in the text, see Figure 3. The video will then open in a new tab/window. You can insert a link in Graasp by selecting the word(s) and then press "Ctrl K" or the Insert link icon in the text editor. A pop-up window will appear (see Figure 3) where you can insert the URL of the video.

Make ILSs which are mainly sequential

Issue: It is possible to write an ILS which requires a student to scroll up and down and move backwards and forwards between tabs to complete the lesson. However, this can lead to unnecessary errors by students who do not always read detailed instructions.

Recommendation: Where possible, even if this means repeating a lab or app, design an ILS in which the student will normally progress downwards through each phase and from left to right through the phases.

Background & analysis: We observed and/or supported 43 students (many on more than one occasion) using ILSs which required some scrolling up and down to revisit and reuse different apps. There were clear instructions in the ILS to say where to go next, but it very often led to errors as the students didn't read the instructions carefully. In some cases, the teacher (or us as support) had to intervene; in others the errors were made.

Introduce students to virtual or remote laboratories

Issue: The composition of remote and virtual experiments to teach topics in science allows employing two concepts: (1) understanding the pattern of a physical process through the virtual experiment and (2) exploring a real mechanism in nature using remote experiments. With its help, a student can understand the whole scientific picture while simultaneously experimenting without physical and time limitations.

Recommendation: Create two different ILSs, each implementing unique features of remote and virtual experiments. To build excitement and engagement in the learning process, use different but connected physical mechanisms to investigate the scientific variables of interest. For example, to teach the Archimedes' principle, the virtual laboratory Splash may be used to explore floating objects, while the Archimedes remote experiment might be applied for the study of relative density or water/fluid displacement.

Background & analysis: The Go-Lab repository consists of more than 400 online (remote and virtual) laboratories. Teachers, especially inexperienced ones, may struggle to implement online laboratories within their curricula. The incorrect application of online labs in classroom instruction could lead to student frustration, and feelings of boredom and demotivation towards the subject studied. Teachers who simultaneously used virtual and remote experiments for the same ILS content reported that students lost interest repeating the same online ILS experiment in two different formats. In this case, students could only recognize a repetition of tasks rather than see the difference between the two experiments provided over the Internet. This suboptimal setup can lead to a misleading attrition rate among students engaging in ILS.

Offer students a series of ILSs to reach an effect on inquiry skills

Issue: Be aware that whereas knowledge effects are immediate, inquiry skills effects take a longer time.

Recommendations: Prepare an introductory ILS just before the one that you would wish to implement. For students who have their first encounter with an app or a laboratory, there must be a time period of getting familiarized with it. This might take a whole ILS, which could be designed for familiarization of students with demanding apps or laboratories. Under this assumption, it would take at least two ILSs in a row to see some first positive effects on student inquiry skills.

Taking a student-centred approach to assessment, we would need to evaluate student ability to undertake learning activities in different contexts, instead of just using pre- and post-test (both pre-specified) instruments. In that regard, we would expect that any gains in student inquiry skills would be revealed as long as they would effectively deal with a novel context of inquiry. This would mean that we should plan at least two ILS in a row to be able to track student progress in the first ILS.

Background & analysis. Common study 1 (see Annex 2) showed that improvement in metacognitive cognitive processes fostered inquiry skills of students when they worked in a new context of inquiry. Specifically, improvement in their ability to apply knowledge they had previously gained enhanced their performance in formulating hypotheses.

Common study 2 (see Annex 2) was planned to let students go through three ILS in a row. This study revealed some effects on inquiry skills but these primarily referred to student learning products).

Inter-contextual transfer of skills was also highlighted as a result of the synergy of using more than one app in the same ILS (Hovardas et al. under review1); see Annex 2 - Study 6. Namely, skills acquired in an ILS with the Hypothesis Scratchpad and the Experimental Design Tool were employed to carry out learning tasks in a subsequent ILS.

A more theoretical perspective would point towards model-based science inquiry (Hovardas et al. under review2); see Annex - Study 8. A prototypical design of model-based science inquiry would take the form of two ILS in a row, where students would first explore the phenomenon under study and identify the basic variables to work with and construct a model (first ILS). The next ILS would allow for simulating the model in a virtual laboratory.

Hovardas, T., Xenofontos, N., & Zacharia, Z. (under review). Examining the effect of a hypothesis formulation tool and an experiment design tool on students' learning when using web-based science virtual labs in an inquiry context. In: I. Levin, & D. Tsybulsky (Eds.), *Digital tools and solutions for inquiry based STEM learning*. IGI Global, under review.

Hovardas, T., Pedaste, M., Zacharia, Z., & de Jong, T. (under review). Unravelling hidden assumptions in virtual laboratories: A strategy of designing model-based science inquiry in computer-supported learning environments. In: A. K.M. Azad, M. Auer, A. Edwards, & T. de Jong (Eds.), *Cyber-physical laboratories in engineering and science education*. Springer, under review.

3.2 Characteristics of a good ILS

<u>Put the lab work in a context</u>

Issue: Students do experiments but don't see what the results mean and what the connection is with things they experience in daily life.

Recommendation: Put the Lab work in a context. Don't let the students do plain experiments. Presenting a context is not an aim in itself. By putting the experiment in a context the students can see why the experiment is important and see what their findings mean and where they can be applied.

Background & analysis: The new curricula in Physics and Chemistry in the Netherlands (that are implemented in the previous years) are based on the context-concepts approach, which is also known as context-based science education. In this approach real life problems are the starting point of lessons and experiments. As such it is a form of problem based learning.

Contexts might be used for a several reasons such as to get students more interested in science, to illustrate the relevance of scientific knowledge, to improve memory of such knowledge or to make students competent in using science in real life.

The use of contexts however is a topic of discussion. Some teachers don't think that it is possible to teach all important concepts and principles based on meaningful contexts. Furthermore, they state that by using contexts too much non-scientific content is introduced in the curriculum.

Create facilities in an ILS to revive prior knowledge

Issue: Misconceptions and gaps in student knowledge can greatly impact student learning. If the gap is too big students will not be able to relate the content of the ILS to their prior knowledge. This will make it difficult for them to give meaning to the things they do in the ILS.

Recommendation: Apart from raising curiosity and gaining attention an important element of the Orientation phase is activation of the prior knowledge. This can be done in several ways. For instance, by giving students a quiz with questions that refer to things they have already learned. Or by asking students to make a concept map which graphically organizes the concepts that they already know (and their relationships). By doing this the students get a kind of mental hooks to which they can connect the new information.

Background & analysis: In a workshop with teacher trainers in May 2016 a discussion evolved around the requirements for doing inquiry. One of the requirements that all participants agreed upon was that there is a close fit with prior knowledge.

In many ILSs much attention is given to the new knowledge that students will learn and limited attention is given to the activation of prior knowledge. On golabz.eu there are a few apps that could be used to activate prior knowledge like the concept mapper or the quiz tool. The Concept Mapper tool lets learners create concept maps, to get an overview of the key concepts and their relations in a scientific domain. They can define their own concepts and relations or choose concepts from a list of predefined terms which can be edited by the teacher (http://www.golabz.eu/content/go-lab-concept-mapper). With the quiz tool teachers can create quizzes containing multiple-choice, open answer and two-way (yes/no) questions. The questions, possible answers and feedback to the student can be edited interactively in the configuration (http://www.golabz.eu/apps/quiz-tool).

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 )

Create interactive and stimulating ILSs

Issue: As soon as students are using a computer (or other interactive device) they appear to expect a high degree of interaction.

Recommendation: Design ILSs which are as interactive, stimulating, and enjoyable as possible, for the target age groups of students. Avoid long chunks of text reading wherever possible.

Background & analysis: In multiple observations of student interaction with ILSs, we have observed students skipping over any long chunks of text, and then sometimes making mistakes because they have not read the text. This has shown up also in analysing their ILS work after the event. This was also frequently raised in ILS usability feedback from students and featured as one of the major themes in D3.3 (Section 4.1, Th03: "Some students skim over any material (pedagogical, scientific or UI guidance) which is not interactive or engaging - especially large amounts of text, and especially younger students")

Organize text, tools, and videos in meaningful units

Issue: Inquiry Learning Spaces include by default five phases. In some cases, the content per phases can become very extensive. If a phase contains very much information in the form of text, tools and videos students can easily get lost. Students need to scroll a lot and get lost and are be unable to find the information that they need. Or they are uncertain when to continue to the next phase. The risk that they accidently skip parts is considerable.

Recommendations: Go-Lab helps teachers to organize the learning environment by offering the five default phases. However, it is still important to think carefully about how to organize text, tools, and videos within these phases. Make sure to restrict the amount of information per phase and limit scrolling to a minimum. To achieve this consider adding extra phases and split up tasks for your students. Make sure to balance text, videos and tools wisely. If an image, tool or video is mentioned in the text, it should be just above or below the corresponding text. Both should be visible on the screen at the same time and students should not have to scroll down to find the tool or image corresponding to your instruction. Add prompts or motivational comments to guide your students through the ILS. Especially information on when to proceed to the next phase, or go back to a previous one, is useful. For example, 'well done, you now finished your first assignment' or 'When you have done enough experiments to answer your research question you can continue to the conclusion phase'. Check the stand alone view of the ILS regularly when designing an ILS to check the students' view of the ILS.

Background & analysis: Many teachers indicated that students had problems navigating the ILS. Their students had difficulty locating the tools or were unable to decide when to progress to a next phase and just stopped. Others would progress to soon ending up with conclusions that are unreliable and thus lead to limited learning gains. Research also shows that students need support in regulating their inquiries (Manlove, Lazonder & Jong, 2006). Mayer (2003) describes that students learn more deeply if both words and pictures or animations are combined. A well-designed multimedia environment takes in account the spatial contiguity effect. This means that corresponding words and pictures or animations should be presented near to each other on the page or screen to foster learning. This will support students in integrating both visual and verbal information and stimulate active learning.

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. Learning and instruction,13(2), 125-139.

Manlove, S., Lazonder, A. W., & Jong, T. D. (2006). Regulative support for collaborative scientific inquiry learning. *Journal of Computer Assisted Learning*,*22*(2), 87-98.

Emphasize the experimental phase

Issue: Students sometimes think they already know the answer to a research question but their ideas are incorrect. Because of this, they often conduct very few experiments and hence, find it difficult to analyse the results from their experiments, which disables them to reach conclusions.

Recommendations: Monitor students' behaviours and knowledge. If students have incorrect ideas about certain domain, make sure that they conduct enough experiments to be able to adjust their initial ideas and draw correct conclusions instead.

Once they have conducted enough useful experiments, but fail to analyse their results, show them how to better organise their data to draw meaningful conclusions.

Background & analysis: This behaviour was found in experimental studies we conducted with the EDT. Students sometimes raised their hands to tell that they had finished conducting all the experiments, but when we checked, they had conducted very few experiments and had not reached correct conclusions.

One of teachers for the Greek case studies, mentioned the following when asked about the different phases of inquiry:

"Many times I caught myself spending more time on the first 2 phases, especially when it was a new topic, and less time on the experiment. But I think it is the experiment and the formation of hypotheses where the weight should be put on."

Or a Spanish teacher when explaining where the effort had to be done:

"… mostly concentrated in conceptualization and experimentation. During the conceptualization phase they had to write some hypotheses, and this was not that easy for them. Students wanted to write hypothesis that were true from the very beginning, they wanted to be sure that at the end the answer was going to be correct. It was hard for them to understand that a hypothesis is not true or false from the very beginning. The experimentation phase helped the students to solve these hypotheses. During the activity I explained them the scientific method, and at the end they "aligned" hypos-experiment-answers, so from my view point, they improve their scientific reasoning, even in this very simple scenario."

Support students in setting up their experiments

Issue: Students have difficulties designing experiments.

Recommendations: Check students' experiments and their understanding of the topic of investigation when they have finished their investigations. If they have designed and/or conducted meaningless experiments, point out where and how they can improve their experiment design. Help by asking them what they did and give them suggestions on how to set up experiments that allow them to draw conclusions on research questions. For example, using extreme numbers in their experiments may help them to explore the boundaries of a domain; designing and conducting an experiment, then observe what happens, and based on the outcome design a new experiment also helps them to get a first understanding of the domain; varying just one variable and controlling for all other variables may help them to understand the effect of the varied variable on the results when they have a first understanding of the domain.

Background & analysis: This recommendation is based on classroom observations during an experiment with the EDT and a quick look at the log files from this study. Even though we found that the Experiment Design Tool helped students with lower prior knowledge gain more knowledge than when they could not make use of the EDT, they sometimes still experience difficulties in designing experiments and as a result base their conclusion on experiments that were not properly designed. We still need to conduct most of the log file analysis, but we could already distinguish the proposed strategies of students who reached correct conclusions (Annex 2).

Encourage students' reflection capabilities with the Go-Lab reflection tool in order to also support better inquiry learning outcomes

Issue: Reflection is an important strategy for students to improve their learning and derive meaningful insights from their experiences. However, reflection does not usually occur spontaneously since most students are not capable of reflecting on their learning without guidance.

Recommendation: Reflection is an important cognitive process for students in order for them to learn from their learning. Through reflection students analyse what they have done during the learning process. During their reflection, they look back on a specific learning phase (e.g., how successfully they managed to formulate their research question) or their whole learning experience (e.g., what were the most difficult parts of the learning process). Reflection should be planned by the learner in order to achieve a maximum outcome. However, in reality, students in school often fail to plan their reflection. This is mostly because students are not capable of reflecting on their learning without guidance; thus, it is important to integrate specific scaffolds that guide students towards reflection. This can be done through guiding questions activating the reflection process or prompts reminding students to reflect on a specific learning phase or the whole learning process. To benefit from reflection, scaffolds should be included in the learning process for a maximum outcome.

Background & analysis: In our study (see Appendix Study Y) a rubric for assessing students' reflections was created based on a coding scheme proposed by Poldner et al. (2012). Their coding scheme distinguishes five levels of reflection (presented in hierarchical order): description (descriptions of the difficulties that the student had), justification (rationale or logical explanation for the difficulties), critique (explanation and evaluation of the difficulties), dialogue (critical review of different solutions or alternative methods) and transfer (how the next action becomes different or better than the previous action).

In a Go-Lab ILS using the Reflection Tool at the end of the inquiry activity, students were asked to reflect on two reflective questions. The first question focused on detecting difficulties ("Which inquiry phase was the most difficult for you and why?") that students encountered during the inquiry task, and the second question addressed conducting similar studies in the future ("What would you do differently the next time you conduct an inquiry investigation?"). The results of showed that most students tend to reflect on lower levels of reflection. The highest reflection levels (critique, dialogue and transfer) were not detected at all. In addition, a non-parametric Mann-Whitney U-test revealed that the students who formulated conclusions at a high quality level also scored higher on the reflection level ($Z=-2.574$; $p<0.01$). Thus, more guidance to help students improve their reflection may also help support students in achieving higher quality inquiry learning outcomes.

Mäeots, M., Siiman, L., Kori, K., Eelmets, M., Pedaste, M., & Anjewierden, A. (2016). The role of a reflection tool in enhancing students' reflection. In Proceedings of the 10th International Technology, Education and Development Conference (INTED), pp. 1892−1900.

Mäeots, M., Siiman, L., Kori, K., & Pedaste, M. (2016). Relation between students' reflection levels and their inquiry learning outcomes. In Proceedings of the 8th annual International Conference on Education and New Learning Technologies (EDULEARN), pp. 5558−5564.

Poldner, E., Simons, P. R. J., Wijngaards, G., & Van der Schaaf, M. F. (2012). Quantitative content analysis procedures to analyse students' reflective essays: A methodological review of psychometric and edumetric aspects. Educational Research Review, 7(1), 19-37.

3.3 Configuring apps to level of experience or prior knowledge

Balance the amount and kind of tools employed

Issue: Go-Lab offers a broad range of effective tools, to help your students with various tasks. Students will have to get to know each tool you include. It will take them some time to figure out how to work with them. If you include too many tools, they may get overwhelmed.

Recommendations: If students work with Go-Lab for the first time, make sure not use too many tools. Most of the Go-Lab tools are quite intuitively and an effort is made to make sure that the user interface of each tool is similar. Still, students have to get familiar with each tool. Students need to put effort in to figure out how to work with them. That effort consequently won't be spent at the actual learning task at hand. There is not a set number that can be considered optimal, since this will depend on the level of the students, their inquiry skills, their ICT skills and the complexity of the chosen tools. However, when students first use an ILS two or three is probably more than enough. Choose these tools carefully. Make sure not just to include the tools that are easy to work with, but the tools that are most beneficial for students and best support the learning goals of the ILS. This will help them realize the added value of the tools. Once your students are more familiar with Go-Lab, you can include more tools.

Background & analysis: The amount of mental effort that a learner can use is limited. We call this mental effort cognitive load and it is restricted by the limited working memory (Sweller, 1988). Cognitive load is highly influenced by the number of novel elements in learning memory. (Kirschner, Ayres & Chandler, 2011). So if a learning environment contains many novel elements, the cognitive load will be very high. Students will need all their mental effort to understand these novel elements, which will leave little room left for actual learning. However, once students are familiar with a tool, it may actually help to reduce the cognitive load. The inquiry apps that Go-Lab offer scaffold the learner in several ways. They help structuring the complex inquiry tasks and help them focus on the things that are relevant for learning. Because they take over some parts of the inquiry task and limit the options that are available to the students, the task becomes better manageable (Hmelo-Silver, Duncan & Chinn, 2007).

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning Cognitive science, 12(2), 257-285.

Kirschner, P. A., Ayres, P., & Chandler, P. (2011). Contemporary cognitive load theory research: The good, the bad and the ugly. Computers in Human Behavior, 27(1), 99-105.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). Educational psychologist, 42(2), 99-107.

Add instruction videos about the tools

Issue: Though most of our tools are quite intuitive, students do need some explanations how to work with them. Most teacher will choose to give a quick walk-through of an ILS at the beginning of class, explaining all the different tools. Additionally, each tool has a help function and in most ILSs a written instruction is provided. Despite all these efforts, many students still have trouble working with some of the tools. If there are many question about these type of issues, it will disrupt the work of students.

Recommendations: Include instruction videos about the tools. Go-Lab offers very good short videos that explain exactly how to use a tool. Though these videos are aimed at teachers, they can easily be used in an ILS to benefit your students as well. These videos will display the sequence of task just as your students will and are easy to follow. Students can choose to watch the videos or not, depending on their own needs, and can choose to fast forward to the parts that are useful for them.

Background & analysis: As indicated in the recommendations ‘too many tools’, students need some time to familiarize with the inquiry tools. Instructional videos can support these processes. Teacher indicate that they get many questions about the tools and how to work with them, even though extensive written explanations were given in the ILS and the tool itself. All of them indicate that students simply don’t read these instructions. A Dutch teacher took the effort to make his own instructional video for one of our tools and included it in the ILS. This proved to be very effective. This also supported by research from van der Meij & van der Meij (2014) who found that learners using videos tutorials performed significantly better than students using a paper-based tutorial on software task.

van der Meij, H., & van der Meij, J. (2014). A comparison of paper-based and video tutorials for software learning. Computers & education, 78, 150-159.

Stimulate students to spend sufficient time on an app or let them return later to the app to complete it

Issue: Students sometimes tend to use too little time for an app or the design stimulates them to use too little time.

Recommendation: Let students interact with apps and laboratories adequately and allocate enough time in the learning activity sequence so that students could have this necessary interaction. There seems to be a minimum amount of time that should be spent on a task, while working with a tool or in a virtual laboratory, so that students would effectively execute a series of learning activities.

When less time than this threshold had been spent during a learning activity sequence, then the remainder should be devoted to working with tools and labs, when students re-visit former steps in their trajectories to re-work their learning products. For instance, if students had not identified all variables needed to undertake an experimentation or if they had not concluded all experimental trials to address a hypothesis, then they would need to move backwards in the activity sequence and devote additional time to working with the Hypothesis Scratchpad, the Experiment Design Tool and the virtual laboratory. This retrospective action might compensate for the time required to complete basic requirements of designing or executing a valid experiment. Retrospective action might also be beneficial in terms of facilitating metacognitive awareness of the learning activity sequence.

However, enough time for interaction with apps and laboratories does not mean as much as one wishes to have! There is not only a minimum time requirement to handle apps and laboratories but there is also a maximum threshold, after which no learning gains are detected any more or after which student performance might even deteriorate. Increased time spent on an app or laboratory might indicate that students might be trapped in an unproductive trajectory.

Background & analysis: There can be multiple designs which might foster retrospective action, and which might build on synergies between software scaffolds. For instance, students could be confronted with a problematization when they would be ready to construct a graph in the Data Viewer. The Data Viewer might offer students only one variable (e.g., the dependent variable) to construct their graph, and in this case students would need to identify the independent variable to plot. This option could be operationalized by linking the Data Viewer to a virtual laboratory (e.g., the Electrical Circuit Lab) with a data set container.

In an alternative linkage, students might be offered more than two variables to construct their graph, and in this case they would need to screen variables and select the dependent and independent variable to accomplish the graphing task. This option might be operationalized through a linkage of the Data Viewer with the Experiment Design Tool.

Both designs were employed in an implementation study in the frame of the Go-Lab project and they both triggered retrospective action (Xenofontos et al); see 1.8. This study revealed, indeed, that there is a time threshold needed to accomplish a desired learning outcome.

Adding up these time requirements across apps, then there are considerable implications for the timeline of phases of an ILS or complete ILSs. Students need a minimum time to profit from an ILS, but there could also be a maximum time. However, students will not gain extra knowledge after this maximum time, and it may even be worse for them. Indeed, this adverse effect was detected when working with the Electrical Circuit Lab (Xenofontos et al. (under review); see Annex 2 - Study 8 to be added by UCY). On the contrary, when re-visiting the Electrical Circuit Lab during retrospective action (i.e., after the designated learning activity sequence had ended and students went backwards to tasks already encountered), time-on-task proved beneficial for student knowledge.

In another experimental study, an initial ILS design which likely focused too much of students' time in the Orientation phase relative to the other inquiry phases did not result in an improvement of students' inquiry skills. However, a follow-up study which slightly revised the ILS to eliminate the time consuming aspects of the ILS resulted in students achieving significant improvements in their inquiry skills after their learning experience with the revised Go-Lab intervention (see 1.8; Siiman et al. 2016). One of the case study teachers having noticed this issue, reflected on what she would change in her practice the following time she would implement the same ILS (see Annex 5): "I would spend less time in the introduction and theoretical framework and spend more time in the investigation part of the model itself. I would change the distribution of time between the first and following phases."

Xenofontos, N., **Hovardas**, T., Zacharia, Z., & de Jong, T. (under review). "Problematizing" scientific inquiry by linking software scaffolds: The effect of time-on-task and navigation on student performance. *Interactive Learning Environments*, under review.

Siiman, L. A., Pedaste, M., Mäeots, M., Zacharia, Z. C., & de Jong, T. (2016). Design and evaluation of an online inquiry learning space to support students' conceptualization inquiry skills. Manuscript submitted for publication.

Design ILSs suitable for a range of abilities

Issue: For an ILS delivered in the classroom context, different students will (rightly) work at different paces, and will benefit from different levels of intellectual challenge. To have bored students who finish early and have had little challenge is not a good outcome.

Recommendation: If you have mixed ability classes, design ILSs which have mandatory activities for all students and some more challenging optional activities for those who finish the mandatory parts early.

Background & analysis: We observed classes where some students finished early, and the teacher had to improvise some extra tasks for them to attempt. In a follow-up interview one teacher made this suggestion, and commented that it is an area where Go-Lab can be better than standard lesson delivery where everyone works at the same pace. One of the research team has also used a similar approach when using worksheets; providing mandatory activities for all and more challenging optional activities for any who finish early.

Configure apps for less experienced students

Issue: Inexperienced users often find it difficult to formulate a (good) hypothesis or research question.

Recommendation: For less experienced students, configure scaffolds to provide increased support and guidance for students. For instance, you could offer many words in the Hypothesis Scratchpad for less experienced students to formulate their hypotheses. As students become more experienced, this support might be gradually removed. For instance, offer less words in the Hypothesis Scratchpad for more experienced students to formulate their hypotheses. If students succeed in formulating their hypotheses with lesser words, then this would be an indication that they had progressed in the skill of formulating hypotheses.

Background & analysis: Students often have difficulties formulating hypotheses and/or research questions. To help them on their way you can configure the apps they use. Many apps can be adjusted to your own wishes when you have added an app to an ILS in Graasp, see http://www.golabz.eu/video/configuration-tools and Figure 5. The (number of) terms that will be displayed can be changed and it's also possible to give students part of a hypothesis/question so that they only have to finish it.

The option to adjust the apps is not available in the student view. So students will not be able to change the setup of the apps.

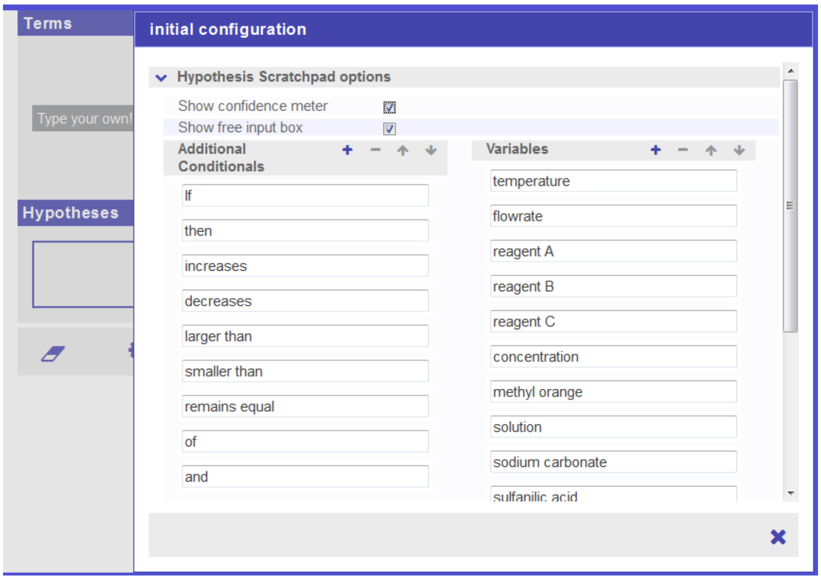


Figure 5. Hypothesis scratchpad configuration.

Configure apps by filling them (partially) with domain content

Issue: Many apps in Go-Lab can be variously configured by teachers.

Recommendation: For less experienced students, configure scaffolds to provide them increased support and guidance. For instance, you would offer many words in the Hypothesis Scratchpad for less experienced students to formulate their hypotheses. As students become more experienced, this support might be gradually removed. For instance, offer lesser words in the Hypothesis Scratchpad for more experienced students to formulate their hypotheses. If students succeed in formulating their hypotheses with lesser words, then this would be an indication that they had progressed in the skill of formulating hypotheses.

Background & analysis: Tools can be used in different configurations based on the desired degree of scaffolding offered to students. An example in this direction is the guidance offered by the Hypothesis Scratchpad. There can be three different configurations of that tool. When all words needed to formulate a hypothesis would be included in the Hypothesis Scratchpad, then structure would get the maximum degree of guidance. When some words are offered to students, then the rest would need to be introduced by students themselves. This configuration would denote a lower degree of guidance as compared to the fully filled scratchpad but it would also introduce a challenge to students in terms of completing the formulation of hypotheses. A third alternative would be to provide no word, which would mean that there would be no guidance at all.

Common study 1 (see Annex 2) showed that students who were supported in their hypothesis formulation by a (filled) hypothesis scratchpad created better hypotheses and were able to transfer this hypothesis formulation skill to a new context. A partially filled scratchpad (the intermediate version containing a subset of words and situated between a fully-fledged scaffold containing all words, on the one hand, and an empty scratchpad containing no word, on the other) may work better than a fully filled scratchpad. This has been the case when examining saturation effects based on correlations between prior skills and skill improvement after the educational intervention. The intermediate configuration of the tool (i.e., the one containing some words) was still beneficial for students with higher prior knowledge. A study on concept maps (D8.3; Chapter 2) also showed that an app that is not preconfigured with content may have no effect on students' performance and suggest to also configure a concept map (partially) by including domain terms and even by presenting a partially completed concept map as a starting point. In another experimental study, revising the design of an ILS to include a partially completed concept map was responsible, in part, for helping students improve their scores on a test of inquiry skills (see Annex 2).

Consider that (advanced) apps may not work for students with very little prior knowledge and may also not have additional value for student with high prior knowledge but will be beneficial for students with an intermediary level of prior knowledge

Issue: Students with distinct levels of prior knowledge need different amounts and forms of support.

Recommendation: If the topic of the ILS is entirely new to students, they need to orient on the topic before starting with their experiments. Make sure that each student has a basic understanding of the topic before they start. If they have this basic knowledge, provide them with tools that structure the task, but that also allow them to explore the topic without too many restrictions. Learners with higher levels of prior knowledge do not need additional support but adding advanced tools (like the EDT) doesn't hamper their learning either.

Background & analysis: In several experiments we found that the effectiveness of adding advanced Go-Lab apps (in this case the EDT) doesn't help students with very low levels of prior knowledge and only started to have an effect when students had average levels of prior knowledge. In two studies (D8.3, Chapter 7, D8.4, Annex 2) we found a significant difference in learning gain between low-intermediate students who used an open version of the EDT compared to students who did not use the open EDT. With open EDT we mean a configuration of the EDT in which students are not obliged to plan a minimum number of experiments and in which they can also vary more than one variable at a time. Students need a starting level of knowledge to be able to profit from (advanced) apps as the EDT.

Provide learners with very low prior knowledge levels with step-by-step instructions

Issue: Students with very low levels of prior knowledge do not gain a lot of knowledge without guidance.

Recommendation: If the topic of the ILS is entirely new to students, they need to orient on the topic before starting with their experiments, or they need to be shown how to perform an inquiry task step-by-step.

If students with very low prior knowledge levels are supposed to build their own knowledge, provide them with tools that guide students in their inquiry task step-by-step.

Background & analysis: In a study with the EDT (D8.3, Chapter 5) we found that students with very low prior knowledge who were guided by a step-by-step version of the EDT gained significantly more knowledge than students who were not guided by the EDT and had to design their own experiments.

Provide learners with low-intermediate prior knowledge levels with tools that structure the task but that also leaves room for exploration

Issue: Students with low-intermediate levels of prior knowledge benefit from specific levels of guidance.

Recommendation: Provide students with low-intermediate levels of prior knowledge with tools that structure the task, but that also allow them to explore the topic without too many restrictions.

Background & analysis: In two studies (D8.3, Chapter 7, D8.4, Annex 2) we found a significant difference in learning gain between low-intermediate students who used an open version of the EDT compared to students who did not use the open EDT. With an open EDT we mean a configuration of the EDT in which students are not obliged to plan a minimum number of experiments and in which they can also vary more than one variable at a time. Obliging them to vary one variable at a time or to plan at least three experimental trials without showing them step-by-step how to design experiments impeded their learning. Showing and giving them the opportunity to use independent and control variables without obliging them to do the things mentioned above, helped them to design and conduct experiments with which they gained more knowledge.

Learners with higher levels of prior knowledge do not need additional support but adding advanced tools (like the EDT) doesn't hamper their learning either.

Notice that giving higher levels of support is not always beneficial

Issue: It is not always the case that giving more support is beneficial for learning

Recommendation: When designing an ILS it may seem the best to give always the highest level of support. This, however may not be the case. There seems to be a delicate interplay with domain and student characteristics that determine the effectiveness of an app. So, always observe very well how apps work with your students and don't be afraid to go to lower levels of support.

Background & analysis: In an experiment with the EDT adding a reflection component to the EDT was not helpful. Students who still had low prior knowledge but who at least had a basic understanding of the domain learned significantly more when they used the EDT but didn't have to reflect on every experiment. In another experiment we found that a less restrictive version of the EDT (that didn't enforce CVS) worked better than a more restricted version, probably because it gave students the freedom to explore and still provided them with sufficient feedback on their behaviour (Annex 2, D8.3 Chapter 7).

Make prudent and considered use of audio content

Issue: If an ILS contains audio material (or videos with an audio component) and is used in a classroom by the students with loudspeakers, then it can lead to cacophony or distractions.

Recommendation: If an ILS is to be used in a classroom context, consider carefully whether, when and how to include any video or audio material, and how to deliver it. The use of headphones or earbuds is possible can create a rather isolationist learning environment and may reduce the ability of the teacher to gain people's attention. If the video/audio material is in the Orientation phase, it may be worth the teacher playing it from the front to the whole group at once. In some cases, a silent video with subtitles may be better than an audible one.

Background & analysis: In teacher workshops we have had occasional concerns raised about audio content and also about the use of headphones. We have observed a teacher intending to deliver video content to the whole class at once, but unable to do so due to technical problems. The teacher asked the class to play the video quietly on their PCs and watch it in twos and threes to minimise the distraction levels. This was far from ideal. We discussed with the teacher afterwards and have raised it as a question in subsequent teacher events.

3.4 Scenarios of use

Consider blended Learning

Issue: A Go-Lab ILS is sometimes perceived by teachers as a vehicle for supporting online labs only. In fact, it can be used effectively for designing and delivering lessons involving a combination of real labs and online labs, or even for lessons involving only real labs.

Recommendation: Consider designing ILSs for learning activities involving a blended combination of real and online labs, or even for lessons involving only real labs. A Go-Lab ILS and Inquiry based learning paradigm can still be useful for aspects such as orientation material, hypothesis generation, experimental design, recording and analysing results, revisiting hypotheses and reflecting on learning. An ILS using virtual labs can also be useful as a preparation activity for a real lab lesson, or for revision, learning reinforcement after a real lab lesson etc. Do not limit your vision.

Background & analysis: We observed and supported delivery of a complex teacher-designed ILS which, over a number of lessons, provided an overall structure for both real lab and virtual lab experiments. The teacher and the students found it very successful and enjoyable, and the students obtained excellent grades for the assessed work.

Encourage collaborative work by students where appropriate

Issue: “Traditional” science teachers, and especially those in countries where ongoing student assessment is a high requirement, sometimes bring forward rather individualistic models of pedagogy into their implementation of Go-Lab. This approach leads to students becoming disengaged by ‘traditional’ teaching and in the long-term, hampers the ability of students to work collaboratively, one of the most critical skills for today’s society.

Recommendation: Explore the potential of Go-Lab lessons for a combination of individual and group work. For instance, the use of apps such as Padlet, and of some of the scenarios such as Jigsaw, Structured Controversy or Six Thinking Hats.

For any sections of the lesson where the students have to be assessed individually, an ILS should support individual efforts, but where collaboration is beneficial, design and write the ILS to encourage this. Imagine the student’s experiential and learning journey through an ILS while you are writing it.

Background & analysis: In various teacher events, including 2015 Summer School, where teachers have demonstrated their own ILSs to each other, any examples involving group work and collaboration have been much admired and emulated. There were requests for extra features to support group working, which led the project team to provide / change some of the scenarios and various other artefacts. In teacher-delivered LS lessons observed in the UK, we have seen teachers pleased at the level of student engagement and learning arising from collaborative activities, and this has been supported by follow-up interviews as well recurring discussions in workshops and sessions across several countries (Italy, Belgium, France, etc.).

Concerning the use of the Go-Lab collaborative apps, in particular the use of Padlet, one of the case studies teachers commented on it: “The collaborative learning tool, which was the

Padlet, was used very easily and well and perhaps as one of the means that helped engage students." (see Annex 5).

Balance the mix of collaborative and individual work for students

Issue: Students are not engaged by traditional teaching anymore (with the student working individually) and most of the times, technology in the classroom is not used adequately to support student collaboration, as a skill for the future.

Recommendation: Make sure that during the implementation and depending on the phase, students get the possibility to work both individually and collaboratively.

Background & analysis: One of the critical skills needed for students to be prepared for once they leave school is the ability to collaborate, underpinning any career path they take. In the case of STEM education, Go-Lab can facilitate the development of this ability alongside much needed inquiry skills. We advise the use of different collaborative/individual work formats in the classroom depending on the topic, objectives and student level.

One of the Case Studies Teacher (see Annex 5) expressed the view that Go-Lab helps student collaboration "exceptionally" and this is very important as often 2 or 3 students have to share one computer, and thus need to exchange opinions and agree before working on the ILS. She also suggested that asking the teams at the end of each unit to prepare a presentation sharing the findings of their inquiries was both beneficial for and enjoyable by the students.

Use different kinds of representations and different means of expression

Issue: Given the existing curriculum restrictions teachers have to face and competing resources they have to use; a frequent question is posed: How much time should students spend working with Go-Lab in the classroom?

Recommendation: Use Go-Lab in conjunction with other tools and real labs in the classroom to support appropriate learning outcomes. In creating an ILS incorporate the use of various media and representations (e.g. text, video, pictures, graphs) to address students' different learning styles as well as familiarise them with different kinds of representation and media of expression.

Background and analysis: Evidence is accumulating that Technology Enhanced Learning inquiry environments provide students with genuinely effective learning opportunities and large scale studies show that, on different outcome measures, TEL-based inquiry outperforms more direct approaches to instruction (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Deslauriers & Wieman, 2011; Eysink et al., 2009; Marusić & Slisko, 2012; Scalise et al., 2011; Smetana & Bell, 2012). These promising results, however, only hold when the inquiry process is structured and scaffolded. Scaffolds thus play a pivotal role in inquiry learning. The two common research studies performed in Go-Lab have indeed shown the learning impact it has had on students and the important role its scaffolds (e.g. to create hypothesis, to enhance collaboration and reflection, etc.) have played in this. However, there could still be a concern about how and how much Go-Lab should be used. To answer this concern one needs to say that as with all innovative tools, environments or methods, there are not to fit all purposes and cannot cover every student or teacher need. They should be used in a complementary way to other methods or tools available for the purposes and learning outcomes they can best serve. Advanced learning environments, like Go-Lab can without a doubt serve very well (and better than other TEL environments) a number of these learning outcomes, but there should be always space in the curriculum for hands-on practical or paper and pencil work as these can enhance additional essential science representations and skills. Indeed, one of the big strengths of Go-Lab is that it can flexibly incorporate these other media of learning. Similarly, Graasp allows the use of different kinds of representation (e.g. text, video, pictures, graphs) in the creation of an ILS, recognising the value of using a variety of means of expression and for learning. One of the case study teachers (see Annex 5) recognise the benefit of multiple representations for the students: "I think that the lesson went well enough or even very well, I am very satisfied. The students were activated in the discussion and all showed interest. All kept notes and formulated hypotheses. They arrived at conclusions both from the graph representation and the algebraic one."

3.5 Monitoring

Monitor students' learning to estimate how much time is needed for inquiry instruction

Issue: Open-ended inquiry takes longer than structured and guided inquiry, and is most appropriate for students already comfortable with completing inquiry activities. For novice learners it is useful to adapt an ILS to fit the time constraints of a classroom lesson. To determine which parts of an ILS may take too long for beginners, then it is useful for a teacher to use the Go-Lab learning analytics apps to monitor the progress of students, and if a section is found to take too long then revise it appropriately.

Recommendation: The Go-Lab environment offers teachers unique learning analytics apps to monitor the real-time progress of students, as well as easily visualise the recorded actions of students after they have finished working with an ILS. Using these apps can help teachers quickly identify students who need support and feedback during in-class Go-Lab activities (e.g. a student is spending too much time a particular task and has not moved on to the next step). In our Go-Lab classroom trials we have used the Go-Lab learning analytics app Student time spent to monitor the real-time progress of students in an ILS and the Go-Lab learning analytics app Action Statistics to estimate the amount of student interaction with various Go-Lab apps. In demonstrations to teachers of these Go-Lab learning analytics apps, teachers express positive feedback about the potential usefulness of these apps. Monitoring learners' progress and outcomes with Go-Lab learning analytics apps is one useful way for teachers to become more aware of what and how well students are learning in the classroom, and to adjust teaching if necessary.

Background & analysis: A study (see Annex 2; Siiman et al. 2016) investigated the effectiveness of a Go-Lab ILS and found that although the initial version of the ILS did not show significant benefits, a revised version of the ILS did. The revisions that were made to the ILS design mainly focused on ensuring that students could progress through each of the inquiry tasks within the allocated class time. In the initial study, a researcher physically observed the students and how much time they were spending on various inquiry tasks. In the follow-up study, the researcher could use the Go-Lab monitoring apps to check that students had completed inquiry tasks in various phases of the ILS and were working at reasonable pace. A more systematic understanding of how students' use their time in an ILS may help teachers and instructional designers better adapt computer-based inquiry activities for use in different contexts and for varying classroom time durations.

Siiman, L. A., Pedaste, M., Mäeots, M., Zacharia, Z. C., & de Jong, T. (2016). Design and evaluation of an online inquiry learning space to support students' conceptualization inquiry skills. Manuscript submitted for publication.

Enact on-the-fly formative assessment

Issue: Select a number of central learning products during the learning activity sequence, in order to focus on them and enact on-the-fly assessment.

Recommendation: For effectively executing an experimentation, hypotheses and experimental designs might be quite insightful in revealing student progress. Hypotheses formulated by students in the Hypothesis Scratchpad and their experimental designs prepared by the Experiment Design Tool would provide a quick and most reliable overview of their progression. Concentrate on the variables students have selected, how they have categorized these variables (e.g., dependent variables, variables remaining constant, independent variables), and how many experimental trials they have planned.

Background & analysis: A substantial number of formative assessment formats have been using a wide array of instruments to diagnose student performance, such as multiple-choice items. Such instruments, however, are external to the learning activity sequence that students follow. Moreover, data collection by means of analogous instruments would necessitate allocation of additional time for data analysis, and this would endanger the proper timing of teacher feedback. Using learning products for the purpose of enacting formative assessment would shorten considerably the time frame ranging from diagnosis of student performance to provision of teacher feedback (Hovardas 2016). To facilitate that interaction between the teacher and students, teachers can employ the Teacher Feedback application from the Golabz set of apps.

The learning products, which would be selected by the teacher for such a procedure, would readily reveal crucial aspects of student performance (e.g., the skill to identify variables) that would denote student progression up to a certain point in the learning activity sequence. These learning products would also play a crucial role for the forthcoming activities. For instance, if a student had not identified the variables involved in an experimentation, then tasks undertaken in a virtual laboratory would carry along that weakness. The teacher would diagnose student progression by concentrating on these learning products and he/she would be ready to provide timely feedback, when this would be required.

Hovardas, T. (2016). A learning progression should address regression: Insights from developing non-linear reasoning in ecology. Journ*al of Research in Science Teaching*, DOI: 10.1002/tea.21330.

3.6 Recommendations to support teachers' work and involvement

Prepare teachers and students in advance before introducing them to the new pedagogical styles and roles in learning:

Issue: When Go-Lab is first introduced into a school where conventional learning methods have been previously used, the roles of teachers and students in learning can significantly change.

Most of the learning material is either in the ILS or will be discovered by the students during the lesson. Therefore, teachers do not need to be seen as dispensers of knowledge adopting a didactic style; instead they will adopt a role of facilitating, supporting, encouraging, monitoring and assisting, but not one of leading or dictating.

Similarly, students need to accept more responsibility for the direction and pace and effectiveness of their own learning.

Recommendation: Plan well in advance how to make teachers aware of the new educational dimensions in order for them to be personally prepared for a change on their teaching style, and prepare their students for a change of learning style.

Background & analysis: This has been commented on by a number of teachers who have practical experience of introducing Go-Lab learning into their schools.

One teacher wrote, reflecting on her implementation of ILSs for 10 lessons (see Annex 5):

"I was able to step back as a teacher, more than I was expecting. As students progressed through the ILS my role became increasingly guide and facilitator rather than instructor. The students' own creativity began to show during the lessons, and they became more inquisitive … the fact that I can adapt my teaching to incorporate a new teaching style has also boosted my confidence. I feel that, with additional use of Go-Lab, I can encourage students to become more independent thinkers, with myself as a mediator and support in the lessons."

In addition, some teachers have speculated that Go-Lab could support "flip learning" in which the main learning input takes place outside of the classroom, and classroom sessions are used for guided reflection and concept formational activities.

Encourage collaborative work by teachers

Issue: Many teachers don't think they have enough ICT skills (and time) to develop their own ILS. And although there is an extensive support section on the Golabz site this thought keeps them from trying to develop their own lesson material.

Recommendation: Teachers can work collaboratively on an ILS so they can divide tasks and support each other, and to better root the experience in the organization.

Background & analysis: In the questionnaire that was given to teachers in the practice reflection workshops, many respondents indicated that one of the main barriers was the lack of teacher's ICT literacy. This was also mentioned in many other workshops. Together with a lack of time this is the main reason that teachers are hesitant to develop their own materials using Graasp. A way to diminish these two barriers could be to let teachers work collaboratively on an ILS so they can divide tasks and support each other. In Graasp several authors can be owners/editors of an ILS. After one author has created an ILS (s)he can invite others (who need to have a Graasp account) to become a member of this ILS. New members automatically get the role of "Viewer". The owner of the ILS can change this role to "Owner" or Editor (see Figure 6). For more information see http://www.golabz.eu/video/managing-your-ils-graasp. In the Support section http://www.golabz.eu/support there is large amount of videos, manuals etc. to help (new) users along.

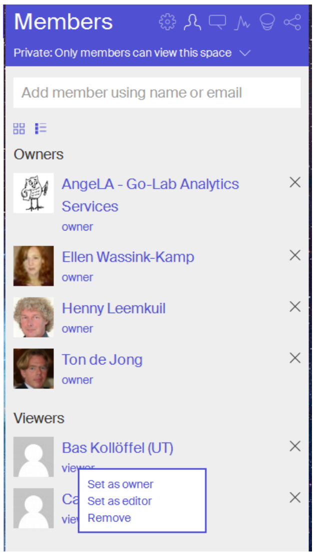


Figure 6. Owner of ILS.

Provide teachers with the opportunities and time to create their own ILSs

Issue: Teachers report serious lack of time in developing their own ILS.

Recommendation: Provide teachers with dedicated time and space to create their own ILSs. In this way they can adapt them better to their own and their school's needs and experiences. For example, one hour covered in their working day dedicated to class/lesson preparation, taking place in the school laboratory. Another approach could be cross-curricular projects where teachers can work together to prepare and build and ILS which can serve several classes with minor adaptations.

Background & analysis: Based on a case study done in France (see Annex 5) with an older, experienced Go-Lab teacher, we have concluded once again that one of the most common issues teachers have is their lack of time to explore the Go-Lab repository, to learn how to use the Graasp environment and to dedicate time to learning by following the resources provided by the Tutoring Platform. Most of the time they are caught up with their actual lesson delivery at school and additional hours go into evaluation, planning and administrative aspects. By putting in a place a formally regulated time slot where teachers are expected to dedicate their time for lesson preparation, their interaction with Go-Lab can rise exponentially.

Provide flexible forms of training and recognition for teachers

Issue: Teachers report serious lack of time to participate in professional development courses. Similarly, schools do not easily release teachers for training.

Recommendation: Professional development courses should offer a variety of models for teacher training, including online- and distance-based courses. They should also include recognition tools for teachers-innovators in their fields

Background & analysis: A common comment teachers made in the Go-Lab practice reflection workshops, which is also reported quite often in the literature is how difficult teachers find to get out of school to attend professional development courses. Go-Lab's response to offering alternative and flexible forms of training include the introduction of the Go-Lab MOOC course, as well as the provision a variety of support teacher/training tools (in different formats, e.g. video, paper and online publications, webinars, fora, etc.). In addition, the use of social media techniques (e.g. badges) were used to award teachers and recognise their engagement and achievement (Govaerts et al., 2015)

Govaerts, S., Cao, Y., Faltin, N., Cherradi, F., Gillet, D. (2015) Tutoring teachers - building an online tutoring platform for the teacher community. In: Ebner, M., Erenli, K., Malaka, R., Pirker, J., Walsh, A.E. (eds.) EiED 2014. CCIS, vol. 486, pp. 39–51. Springer, Heidelberg, pp 39-51. DOI: 10.1007/978-3-319-22017-8_4.

3.7 Scalability Recommendations

3.7.1 How to embed ILSs in the curriculum and the school?

Consider using ILSs in a variety of contexts

Issue: Many teachers imagine Go-Lab is intended for use only in formal lessons, in place of real labs, and think of creating ILSs only for this context.

Recommendation: Use portal, forum and other media to raise awareness of the greater potential of Go-Lab to provide education in multiple contexts; e.g., homework, revising for exams, distance learning, self-directed study, detentions, individual or team project work, excluded pupils, sick pupils, and by teachers providing "cover" for an absent teacher. Provide example ILSs on the portal for these varied contexts of use. An ILS can be designed with varying paths through it, or slightly different copies of an ILS, to allow for different contexts and modes of use.

Background & analysis: In a workshop involving 21 teachers conducted in Bristol, one teacher suggested the suitability of Go-Lab for use by supply teachers when the normal teacher is absent, and in the ensuing conversation teachers suggested a wide range of other contexts where Go-Lab may be appropriate. Since this question has been posed whenever possible in all contacts with teachers. Few teachers think of this spontaneously but when prompted many see the potential. The observation was reported in D3.3 (Th17 in 4.1 Major Themes). Subsequently in a college in Birmingham, UK a teacher excited by this possibility created a huge ILS which would be partly conducted in lessons, partly as homework and partly in other less structured contexts. It proved very effective generating more enthusiasm and greater achievement in the students than expected.

Another teacher in one of the case studies (see Annex 5) also referred to the importance of using Go-Lab for homework, but also as a tool even before the introduction of a topic, so that students have time to interact with the tool in their own time. In addition, she mentioned the use of the environment by students themselves to create their own small ILSs:

"Also the students themselves incorporated the inquiry model and through the platform, at the end of last school year, created their own scenarios, their own small ILSs, or changed already existing ones. In other words the students became the teachers through this programme. It was a group of 20 students with special disposition towards science."

Integrate ILSs in other curriculum activities

Issue: Go-Lab can seem to be a self-contained system for special purposes. This view would limit its applicability unnecessarily.

Recommendation: Envisage Go-Lab as an integral part of the school's science curriculum delivery infrastructure, and explore how it can be integrated with other technical and pedagogical components. E.g., secure password-protected logons for students providing identity authentication, email systems, systems for distributing learning materials such as photos, presentations etc., systems to allow students to submit work for assessment, and to access their marks and feedback, and sometimes other fully-specified learning management environments such as Moodle or Google Classroom.

Background & analysis: Many discrete observations along these lines were made during the Year 3 formative studies reported in D3.3. Subsequently working with teachers in depth as part of WP8, it has become clear that the more visionary and enthusiastic teachers take the holistic view and work on integrating Go-Lab with the school's established technical and pedagogical infrastructure (and sometimes ask the project for help with this). Depending on the school's' software portfolio, the most obvious points for integration may be distributing URLs, submission of student work for marking and providing feedback and marks.

We have observed a wide range of enthusiasm and efforts (and requests for help) to integrate Go-Lab better, as well as some ingenious solutions. For example, one teacher gave students an ILS to complete with a deadline. When the deadline arrived, the teacher modified the ILS to require passwords.

3.7.2 Organizational Measures

Combining school innovations within the school's vision

Issue: A number of school innovations are implemented on an ad-hoc basis and thus any gains achieved are on a small scale and not sustainable.

Recommendation: School leaders and teachers should aspire to incorporate innovations within the school's developmental plan and innovation strategy.

Background & analysis: A wide and sustainable impact is what every innovation aspires to. The relevant literature emphasises how important it is for this to happen that the innovation fits within the school's overall vision and strategy. In an interview with one of the case study school leaders, he pointed out that coordination of the implementation of different innovations in a school is necessary. Absence of such a coordination reduces the likelihood and monitoring of sustainable results. He also pointed out that school meetings which focus on the dissemination of good practices and innovations implemented amongst teachers of the same school are important. A fellow teacher who has used an innovation with positive outcomes for his/her students is the best and most convincing advocate of the innovation. This is supported in the literature by Guskey (....), whose model of teacher change emphasises the importance of experience of successful implementation in change, So that change is primarily an experientially based learning process.

From one of the case study heads of school point of view (see Annex 5): "The activities in school happen without any planning/programme. Usually teachers come with something they have in their minds and say 'I want to do this, it is very good…' etc. Most often you do not want to intervene and say 'don't do this activity, or do this', you let them do it. It does not happen however under a given coordinated framework. And this is where the difficulty is. Now, this difficulty has solutions; it could happen, not only through specific guidance, but also through the philosophy of a school. I think that we, who are 'model' schools, could define our philosophy or have a 'special process' through which these activities should pass, or which will coordinate which activities can come together to bring a result."

Facilitating reasonable curriculum autonomy

Issue: Teachers and school leaders often cite lack of time and flexibility to incorporate new tools and pedagogic methods in their classrooms and schools. Compatibility with the curriculum is one of the issues that any innovation needs to tackle if it is to be adopted more widely.

Recommendation: Policy makers should allow schools some curriculum autonomy, if the latter are to be able to implement widely teaching and learning innovations in their classrooms.

Background & analysis: Compatibility with the curriculum is one of the issues that any innovation needs to tackle if it is to be adopted more widely. Go-Lab through its practice reflection workshops with teachers got useful feedback on the difficulties they faced in using Go-Lab in their classroom and made the necessary adaptations. However, the stricter and more detailed the national curriculum and assessment guidelines are the more difficult teachers have found it to incorporate Go-Lab. An innovation by its character is meant to introduce new features in teaching and learning, so by nature cannot be fully compatible with any national curriculum, unless the latter consists mainly of general statements of capabilities and attitudes students should develop as a result of schooling, and schools have the main responsibility for curriculum content and pedagogy.

A head of school in one of the case studies expressed this constraint in implementing innovations, such as Go-Lab: "Because a big problem is that the educational process is strictly restricted within given frameworks. It gives very few margins to teachers who wish to innovate, to do something different. And if they try to do something different, they will get very tired with all the bureaucratic procedures, etc.. This [Go-Lab] could enter [the curriculum], either if these restrictive guidelines were in different form, or if they gave teachers more freedom to do things. If we see other educational systems, in essence the teacher designs and develops his/her curriculum, his/her programme. Here the teacher does not develop his/her curriculum; a paper comes, which says 'you will do one, two, three'. Then another paper comes to say 'this is how you will do the one', 'you will do these exercises from the two', and 'you will do this lab from the four'. These are very restrictive. Some people in the Ministry, sit down, write a programme and they give it to you. And I, as a teacher, work as if I were given a recipe book. I do not accept this as a Physicist, to work as if I had to follow a recipe book; I could introduce other elements who could bring results. But at this moment, this cannot be done. And this is a very big problem for the introduction of such elements, like Go-Lab, in teaching. And it also an issue of time, restriction of time. But also sometimes if you try to do something, you have all the people on the outside […] saying 'what is this that the school is trying to do?' etc. - when you try to do something outside the pre-defined one by the Ministry. It is certain that it will contribute [positively], but it is very difficult, and if a teacher does not have the disposition to go through this process, s/he says 'I covered the set curriculum until there and I am alright'. This is what usually happens."

Similarly, one of the case studies teachers could not have described the issue better: "The ILSs (we used) related to the curriculum areas that had to be taught [...] but we had to be certain first that we had covered them in the way specified by the curriculum instructions so as to be ready for the exams, so as then to have the margin to ask for additional hours (2 to 3) within the weekly programme to implement the ILSs with the students." (see Annex 5).

Creation of subject folders and a collection of department folders

Issue: Difficulties for teachers to disseminate the project within their school and to produce cross curricular activities in collaboration with their colleagues. There are no tutorials for teachers explaining the creation process of their own ILS or how this were implemented during their lessons.

Recommendations: Creation of a collection of department folders (per school, per department and per subject), that will contain not only the links to the relevant ILSs per subject, but also an explanation of what preceded the ILSs, how the lessons were implemented and other tips & best practices. This structure, should be supported by the development of a regional program for teacher exchange, further enhancing interschool exchange, sharing of best practices and cross-curricular activities and harmonizing curriculum inclusion within the regions.

Background & analysis: This has been commented by a number of experienced teachers who participated in the case studies.

A Greek teacher said regarding adoption in his centre:

“I think that all the results achieved during the last 2 years will serve as perfect examples for dissemination. My scenarios have been implemented, they have worked and they have had results. I have also recorded what students did, and I believe all this might work as a motivation and as an example for other teachers to get involved.”

And regarding cross curricular activities:

“I have heard from the science teachers that they know about the inquiry cycle from the 2nd phase of their ICT training, so it would be easy for them to integrate it in their teaching and create scenarios.”

In addition, teachers complained about the use of computers being strongly limited to the IT teachers (see Annex 5).

Creation of regional clouds

Issue: When referring to scalability, it might be reasonable saying that the greatest challenge exists between schools. Teachers might encounter more or less difficulties when confronting dissemination within their own school, but in this scenario there is no existing contact between teachers or at least one reliable enough.

Recommendations: Creation of regional clouds, sections to be divided per school, per department and per subject. Go-Lab can contribute to the development and organisation of these structures under the guidance of the regional authorities. The idea would be for any teacher to be able to check for an ILS in his language that has been already adapted to comply with the regional curricula, together with other possible resources such as tips for implementation attached. These regional hubs might also include “School tutorials”, where teachers and Head of School get to explain how Go-Lab was implemented in their schools.

Background & analysis: We could state a similar explanation to the one stated for the network creation at school level, with the constraint in this case, that teachers are much more limited (for obvious reasons) to online exchange. Still teacher motivation is a powerful tool and is always generating new opportunities.

“I recommend the teachers to use the ILS even in primary school. From the very beginning, UDeusto team accepted the challenge of using ILS in the primary level.

As I have said, I believe in the Go-Lab project, and I am trying to involve more teachers in my school. For example, the English teacher is going to use the ILS of the Archimedes Principle to teach English using science vocabulary and the Go-Lab platform as an IT tool. We will see the results."

This was said by a Spanish teacher when asked about how to extend the use of Go-lab in the future (see Annex 5).

Development of a regional network Go-Lab Ambassadors

Issue: When referring to scalability, it might be reasonable saying that the greatest challenge exists between schools. Teachers might encounter more or less difficulties when confronting dissemination within their own school, but in this scenario there is no existing contact between teachers or at least one reliable enough.

Recommendations: The creation of a program of regional teacher exchange. "Certified" ILSs designers to implement their lessons in other schools. This kind of activity would further foster interschool exchange, sharing of best practices and cross curricular activities, while harmonizing curriculum inclusion within the regions.

Background & analysis: Very close related to the previous recommendation, this practice would definitely enhance interschool activity. Many teachers participating in Go-Lab workshops and case studies could serve as ideal ambassadors for the Go-Lab project. Similar experience having successfully taken place within other European Science projects (http://www.scientix.eu/web/guest/call-for-teachers-3)

This will can already be observed within our teachers. As mentioned by a teacher during the French case study final interview:

"The exchanges I had with the teachers concerned let me say that the impact is mixed. It takes time to convince colleagues to change their way teaching and adopt new methodologies such flipped classroom or ILS. Sometimes the barrier of language is a problem to overcome.

The Positive thing is that the implementation of Go-Lab open mind for new practices, methods and exchange between teachers all over Europe." (see Annex 5).

Or in the UK:

"Most teachers haven't heard of it. It needs more awareness and publicity. I will be presenting to the science department next term, about my ILS and also about the Summer School." (see Annex 5).

4 Conclusions

As it will become clear from the annexes and was made concrete in the preceding recommendations the collected evaluation data has facilitated and provided the basis for the composition of the recommendations. These are focusing not only in improving teachers' implementations of ILSs but to also provide ideas and possible solutions related to the scalability of the project.

When it comes to the evaluation results though, students' focused common studies demonstrated the importance of scaffolding to support the formulation of hypotheses with preference given to partial scaffolding as a more balanced solution. Moreover, a significant knowledge improvement, which was common across all countries was noticed in the participating students. That was the enhancement of the “Understand” factor.

In teachers' large-scale evaluation the aim was to continue monitoring the impact of the use of Go-Lab tools in their technical skills, IBSE knowledge, use and understanding of online laboratories. Regarding our teachers' profile, the majority that participated in the evaluation were interested in the use of online laboratories and had quite developed pedagogical and technological skills. Most of the Go-Lab teachers had also a solid knowledge and experience on IBSE. The majority of teachers were confident in teaching IBSE to their students and to design related activities. What is interesting though is that there is still a significant number of teachers that do not feel confident using IBSE and consider that they still lack skills in order to successfully apply it. Go-Lab is contributing to teachers understanding of IBSE, as a comparison with the D8.3 findings reveals, but continuous support, good practices and training are needed in order to support more teachers interested in IBSE and help them fully develop the needed skills.

When it comes to their technical skills, the responding teachers were quite confident to use online laboratories and repositories. The use of authoring tools though, was a big challenge for most teachers which also affected their intentions and ways they used the Go-Lab tools. At the end of Pilot phase B we saw a change in teachers’ technical skills with a significant rise in the numbers of teachers that were daring to use the authoring tool. The development of the tutoring platform, the various supportive materials that were made available in the course of the previous years and the training sessions that took place all around Europe, have definitely played their role and contributed to this change. At the end of Pilot phase C though we see that the number of ILS creators remains pretty much the same, while the number of ILS consumers has risen. The growth of the ILS repository that took place during the last year of the project is a direct consequence of the development of teachers’ technical skills which led to the development of a large number of ILSs covering a variety of topics and languages. At the same time, the use of Go-Lab helped teachers to gain familiarity with the basic principles of authoring tools that they can use in producing their own ILSs. As a result we can see that the shift in attitudes regarding the use of Go-Lab that started in Pilot phase B continues in Pilot phase C. Teachers that wish to create ILSs have the capacity to do so, while the outputs of the ILS creation also strengthened the group of ILS consumers.

Students’ large-scale evaluation showed an overall positive attitude towards the use of online laboratories with students being quite skilled in the use of Go-Lab tools. The frequency and type of use of the Go-Lab tools within the classroom showed that there is a preference in using Go-Lab for the duration of the lesson. Students also seemed to be very positive regarding the relevance of studying STEM topics in relation to society and STEM careers. This is an effect that although it cannot be directly attributed to Go-Lab, students' strong interest in performing practical work, is closely related to it.

Annexes

1 Student evaluation (experimental studies)

1.1 Study 1: Scaffolding students' conceptualisation with the question and hypothesis scratchpad

1.1.1 Abstract

Go-Lab deliverable D8.3 described a study (Chapter 3, pp. 29-34) that evaluated the impact of two Go-Lab apps (the Question and Hypothesis Scratchpads) on students' inquiry skills. Assessment relied on pre- and post-tests to measure students' inquiry skills before and after the Go-Lab intervention. In that initial study, the results showed no statistically significant differences between students' pre- and post-test scores. Some potential difficulties that may have influenced the results were documented by two researchers who implemented the study. Their informal observations were discussed in D8.3, and preliminary suggestions to improve the implementation of the Go-Lab intervention were offered, more specifically it was said that,

> *The researchers observed that students from both age groups would benefit enormously from a better understanding of how to budget their time while working in a Go-Lab ILS. It was observed that many students spent an excessive amount of time with the introductory material and thus did not have sufficient time to explore their research questions and hypotheses using the online virtual laboratory.* (p. 33)

This follow-up study aimed to address the specific problems identified in the initial study and redesign the Go-Lab intervention to take into account the proposed suggestions made by the researchers. The same assessment instruments (i.e. inquiry skills pre- and post-tests) used in the initial study were reapplied in an intervention with 28 secondary school students (average age of 17.0 years). The results this time showed a statistically significant improvement in inquiry skills. We discuss the implications of this follow-up study in terms of designing effective Go-Lab interventions. A paper detailing these two studies has been prepared and submitted for publication in an academic journal:

> Siiman, L. A., Pedaste, M., Mäeots, M., Zacharia, Z. C., & de Jong, T. (2016). Design and evaluation of an online inquiry learning space to support students' conceptualization inquiry skills. Manuscript submitted for publication.

1.1.2 Introduction

Stating research questions and formulating hypotheses are two very important inquiry skills for students to develop. Möller, Hartmann, & Mayer (2010) studied four essential inquiry skills ("formulating questions", "generating hypotheses", "investigation planning", and "interpreting data") and reported that formulating questions is an especially challenging inquiry skill for students to acquire. They found in interviews that teachers most often provide the research question(s) for students to study in order to save class time. Generating hypotheses is also identified in the research literature as being particularly difficult because students tend to repeat an effect rather than discover its causes (Sodian, Zoitche, & Carey, 1991), confuse a prediction with a hypothesis (Njoo and de Jong, 1993), or do not identify likely causes (Koslowski, 1996). Thus, there is a need to support and guide students when they encounter inquiry tasks which require stating research questions and/or formulating hypotheses.

In Go-Lab deliverable D8.3 a study (Chapter 3, pp. 29-34) was conducted to evaluate the impact of two Go-Lab apps (the Question and Hypothesis Scratchpads) on students' inquiry skills. The two apps appeared in a Go-Lab ILS called *'Is it good to be beautiful?'* (http://www.golabz.eu/spaces/it-good-be-beautiful), which was designed following the inquiry-based learning framework of Pedaste et al. (2015) and addressed learning goals found in the

Estonian Natural Curriculum related to the domain of evolution. The Question and Hypothesis Scratchpads are Go-Lab inquiry apps based on work by van Joolingen and de Jong (1993). They offer students a structured way to state research questions and formulate hypotheses by dragging-and-dropping terms into an input field. In the study described by D8.3 Chapter 3, a condition with predefined terms in the Question Scratchpad and predefined terms in the Hypothesis Scratchpad was compared to a condition without the presence of these predefined terms. Nonetheless, the results of the initial study in D8.3 showed no statistically significant differences between students' pre- and post-test inquiry skills scores for either of the experimental conditions.

A possible explanation for there being no improvement in inquiry skills was offered in D8.3 based on the informal observations of two researchers who actually implemented the intervention with students. They observed that the initial ILS design did not optimally match the allocated classroom time and specifically pointed out aspects of the ILS design that appeared to impede timely and/or successful completion of inquiry tasks. One apparent problem was that students spent a large amount of time in the first inquiry phase and as a result did not have sufficient time to engage with inquiry tasks in the following four inquiry phases.

In order to study the effect of ILS design on students' development of inquiry skills, we revised the design of the ILS of the initial study and conducted a second follow-up study. The same methodology used in the first study was again used in this follow-up study. Next, we discuss the relevant changes that were made to the ILS design, the results of the follow-up study and the implications these results have in terms of designing *effective* Go-Lab interventions.

1.1.3 Method

The research design and methodology used in D8.3 Chapter 3 was reapplied with a new sample of students using a revised Go-Lab ILS. A researcher helped a teacher implement the Go-Lab intervention with a total of 28 students from a secondary school class. Like in the initial study, the intervention included two conditions: one condition where Go-Lab inquiry apps (i.e. the Question and Hypothesis Scratchpads) in the Conceptualization phase of the ILS displayed predefined terms to help students formulate research questions and hypotheses, and the other condition where the inquiry apps did not display these terms. Evaluation was based on student performance on inquiry skills pre- and post-tests.

1.1.4 Participants

Complete data from 28 students (21.4% boys, 78.6% girls) from a class at a public secondary school in Estonia was collected and analysed for this study. The students ranged in age from 16 to 18 years old ($M = 17.0$, $SD = .74$). All students present in-class during the day of the intervention participated in the study. The students had no previous experience using the Go-Lab learning environment.

1.1.5 Materials

Like in the D8.3 Chapter 3 study, students worked with a Go-Lab ILS called *'Is it good to be beautiful?'* (http://www.golabz.eu/spaces/it-good-be-beautiful) [the Estonian language version actually used in the studies was called *'Kas on hea olla ilus?'* (http://www.golabz.eu/spaces/kas-hea-olla-ilus)]. However, certain aspects of this ILS were revised based on the feedback collected in the initial study. Below we specify the relevant design element changes used in this follow-up study and the reasons for these changes.

Removal of a lengthy video

In the initial study, it was observed that many students spent a disproportionate amount of time in the first inquiry phase (i.e. the Orientation phase) of the ILS, and consequently may not have had sufficient time to formulate or explore their research questions and hypotheses when using the online virtual laboratory. Since students were working with the Go-Lab learning environment for the first time they were not familiar with the structure of the five inquiry phases and were not aware of how much time to allot to each phase. Consequently, the first inquiry phase consumed a disproportionate amount of their time. In order to correct this problem, it was clear that design elements in first phase that were consuming a lot of time needed to be changed. One such design element was a video that was about 8½ in length. However, this length did not account for the extra time spent by Estonian students pausing and rewinding the video to better understand the English language information, as observed by researchers during implementation of the initial study. Clearly, the initial ILS design did not account for this extra time. Therefore, it was decided to revise the ILS design by deleting this video from the ILS.

Inclusion of a collaborative task

As a substitute for the lengthy video, the ILS design was revised by inclusion of task involving the Padlet app. The Padlet app allows students to upload images to a commonly shared “wall” which is seen by all students working in the same ILS. A task was created for students to search the internet and add a domain-relevant picture to the Padlet wall. The purpose of this task was to promote idea sharing between students.

Adding more scaffolding for the Concept Mapper app

Another factor that appeared to increase task time in the Orientation phase was that the Concept Mapper app had minimal scaffolding (i.e., no predefined concepts were displayed to students). Students had to spend time thinking about which new concepts to create and how to connect them to each other. A predefined concept map with concepts and relationships already linked could have sped up this process. In the follow-up study the ILS design was revised to add additional scaffolding to the Concept Mapper app and initialize it to display a partially completed concept map on start-up. This partially completed concept map was thought to better guide students to generate the task outcomes since it provides clear examples of what students are expected to generate. Figure 7 shows how the Concept Mapper app appeared in both the initial study and the follow-up study.

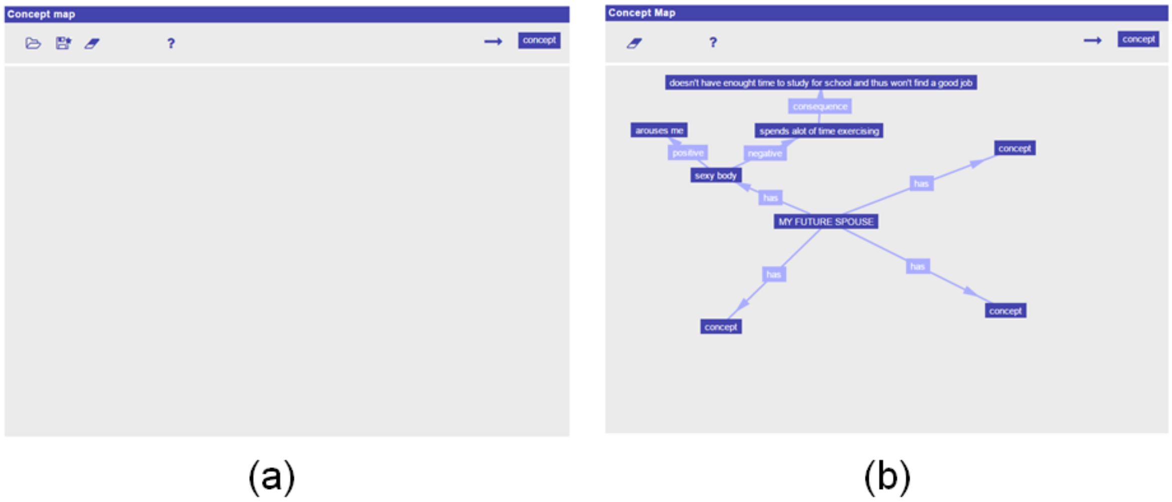


Figure 7. Screenshots of the Concept Mapper app as it appeared in the (a) initial study, and in the (b) follow-up study.

Removal of the EDT app

The Experimental Design Tool (EDT) is a useful Go-Lab inquiry app to support students with planning their scientific experiments. It allows students to select which independent variables to vary or keep constant and which dependent variables to measure. However, several students asked for help when using this tool during the initial study, and proper selection of variables, along with defining values for each experimental trial is a somewhat time-consuming process. Since the main objective of this ILS was to support inquiry skills related to stating research questions and/or formulating hypotheses, it was decided to remove this app and try to minimize the amount of Go-Lab apps in the ILS design. The final ILS design for the follow-up study included 7 Go-Lab apps (the Padlet app, Concept Mapper, Question Scratchpad, Hypothesis Scratchpad, Observation Tool, Conclusion Tool, and the Reflection Tool).

Upgrade of the online laboratory to HTML5

Another revision to the initial study ILS design was to replace the Java laboratory with a HTML5 version. In addition to running on modern web browsers and tablet devices, the HTML5 virtual laboratory constrained the number of variables students could manipulate when making experiments. At the time of the initial study, the *Sexual Selection in Guppies* online laboratory was a Java applet that required installation of the Java plug-in for the simulation to work in a web-browser. In September 2015 the Google Chrome web browser ended support for Java plugins. It was decided to create a new HTML5 compatible version *Sexual Selection in Guppies* online laboratory since the follow-up study would likely rely on students using tablet computers. Figure 8 shows how the online laboratory appeared in both the initial study and the follow-up study.

1.1.6 Assessment of Inquiry Skills

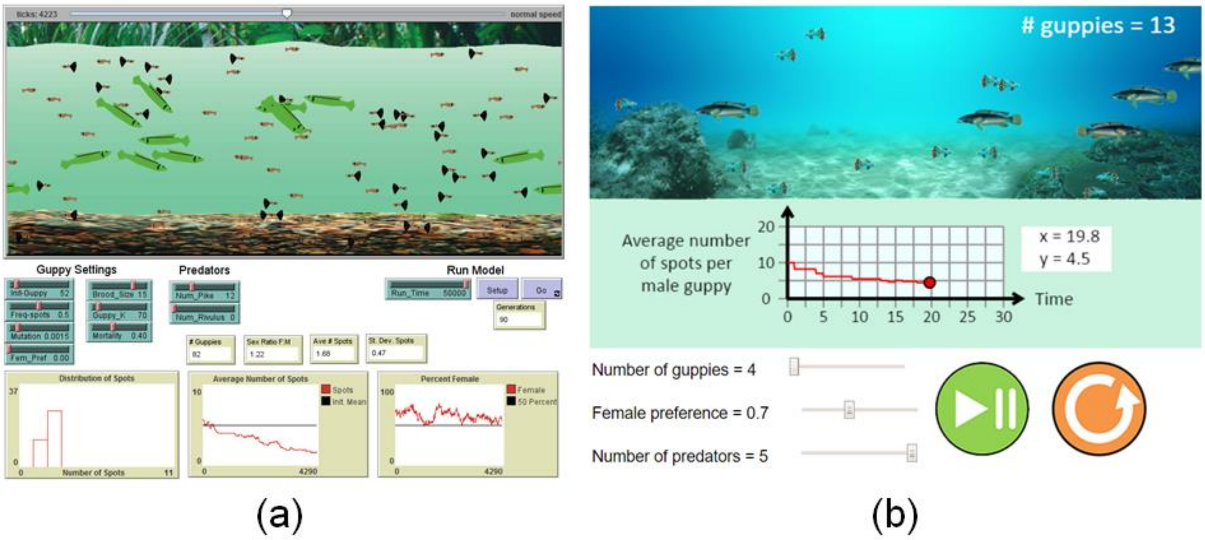


Figure 8. Screenshots of the Sexual Selection in Guppies online laboratory as it appeared in the (a) initial study, and in the (b) follow-up study.

Assessment of inquiry skills was conducted using the Test of the Integrated Science Process Skills (TIPS) developed by Dillashaw and Okey (1980) and the TIPS II by Burns, Okey, & Wise (1985), which is an extended version of the original TIPS. Split-test correlation coefficients between TIPS II and TIPS items show that the two tests are highly equivalent (0.86 and 0.90 respectively), and total test reliabilities for the two tests are 0.82 and 0.86 respectively (Burns, Okey, & Wise, 1985).

In our studies, TIPS was used as the pre-test and TIPS II as the post-test. Furthermore, only items related to measuring two aspects of inquiry skills were selected from the tests: 1) identifying variables (i.e. dependent, independent, and control variables), and 2) identifying and stating hypotheses. These items were selected because, compared to other aspects measured by the tests (operationally defining, graphing and interpreting data, designing investigations), they were judged to be the most relevant to assessing inquiry skills related to stating research questions and/or formulating hypotheses. A sample test item (item 27 from TIPS II) measuring the identifying and stating hypotheses aspect reads as follows:

> *Some students are considering variables that might affect the time it takes for sugar to dissolve in water. They identify the temperature of the water, the amount of sugar and the amount of water as variables to consider. What is a hypothesis the students could test about the time it takes for sugar to dissolve in water?*
> *A. If the amount of sugar is larger, then more water is required to dissolve it.*
> *B. If the water is colder, then it has to be stirred faster to dissolve.*
> *C. If the water is warmer, then more sugar will dissolve.*
> *D. If the water is warmer, then it takes the sugar more time to dissolve.*

As the above sample test item illustrates, the inquiry skills test items in TIPS and TIPS II are domain-general questions that do not require subject-specific knowledge, but instead aim to assess students' comprehension of the set of practices needed to engage in scientific inquiry.

1.1.7 Procedure

Like the initial study, the follow-up study followed a classical experimental design of pre-test, intervention, and post-test, and students were randomly assigned to one of two experimental conditions (i.e. either *with* or *without* predefined terms in the Go-Lab inquiry apps Question Scratchpad and Hypothesis Scratchpad). The study took place during regular school hours. Unlike the initial study, students in the follow-up study worked in groups of 3 to 5 persons to complete the ILS intervention. Nevertheless, students took the pre- and post-tests individually. The pre- and post-tests to measure inquiry skills were administered a few days before and after the Go-Lab intervention and students were allotted 20 minutes to complete these pen-and-paper tests. The Go-Lab intervention was allotted a full classroom period (75 minutes). Students used their schools' tablet computers (including a keyboard dock) to complete the intervention in their regular classroom. A university researcher led the Go-Lab intervention and explained the purpose of the intervention to students at the beginning of the class. He then distributed at random to students one of two URL links, corresponding to the conditions *with* and *without* predefined terms in the Question and Hypothesis Scratchpads, to access the *Is it good to be beautiful?* ILS. Students logged in using their names and the data they created was automatically saved. The researcher was available to answer questions during the intervention and intermittently monitored the amount of progress students made in completing their inquiry tasks.

1.1.8 Results

The results of the inquiry skills pre- and post-tests for this follow-up study are presented in Table 1. For comparison, the initial study results are also included in this table. As mentioned earlier, no significant differences were found in the initial study. However, a Wilcoxon signed-rank test showed significant increases in scores for students who participated in the follow-up study. Follow-up study students in both conditions benefited from the Go-Lab intervention (results for students in the *with* condition showed $Z = -3.516$, $p < .05$, and results for students in the *without* condition were $Z = -3.059$, $p < 0.05$). These results provide direct evidence that the Go-Lab intervention was effective in developing students' inquiry skills.

Table 1. Descriptive statistics of inquiry skills pre- and post-test scores for the initial and follow-up studies for students in the conditions with and without predefined terms in the Question and Hypothesis Scratchpads.

Inquiry Skills Tests *(Max score = 21)*	**With**		**Without**	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev*
Initial study (N = 19)				
Pre-test score	11.58	2.23	12.57	1.72
Posttest score	11.58	2.02	11.29	2.63
Gain score	***0.00***	***2.76***	***-1.29***	***2.50***
Follow-up study (N = 28)				
Pre-test score	12.38	2.53	12.00	2.73
Post-test score	13.75	2.21	13.08	1.08
Gain score	***1.38***	***2.73***	***1.08***	***3.23***

1.1.9 Discussion and Conclusion

Having found evidence that the revised ILS design used in the follow-up study provides a positive improvement in students' inquiry skills, we can consider what impact these results have on the design of effective Go-Lab ILSs. First of all, the main aim of the revisions was to facilitate timely and productive completion of inquiry tasks in the ILS. Most of all the revisions attempted to help students work more efficiently in the Orientation phase. A lengthy video that was part of the initial study was removed to hasten students' progress in the Orientation phase. As a substitute activity to passively watching a video, a task to find and share a meaningful picture via the Padlet app was included to promote idea sharing between students. A final revision in the Orientation phase was to configure the Concept Mapper app to initialize on start-up with a partially completed concept map. In this way students had examples to follow and did not have to think of an original concept map from scratch. Finally, an important revision to the ILS in the initial study was to upgrade the online laboratory from a Java applet to a HTML5 compatible version. This allowed the ILS to be accessible through touch sensitive smart devices. In addition, the number of variables that could be manipulated in the lab was decreased.

The aforementioned revisions led to the result that student inquiry skills test scores improved statistically significantly after working through the revised Go-Lab ILS. In part, the revisions responsible for this improvement are related to several recommendations, but most of all to

- Configure apps by filling them (partially) with domain content
- Stimulate students to spend sufficient time on an app or let them return later to the app to complete it
- Monitor students' inquiry learning
- Don't use too many tools

In conclusion, this follow-up study provides evidence-based support for designing effective inquiry activities using the Go-Lab learning environment. Overall, adaptable online inquiry learning environments may help teachers better align inquiry instruction to their classroom needs. A more systematic understanding of how students' use their time in inquiry learning environments could help teachers and instructional designers better adapt computer-based inquiry activities for use in different contexts and for varying classroom time durations. Further research, such as studies that have explored the use of Go-Lab learning analytics apps to monitor more closely student progress (Hecking, Manske, Bollen, Govaerts, Vozniuk, & Hoppe, 2014; Vozniuk, Govaerts, & Gillet, 2013) may help in building this systematic understanding.

1.1.10 References

Burns, J. C., Okey, J. R., & Wise, K. C. (1985). Development of an integrated process skill test: Tips II. Journal of Research in Science Teaching, 22, 169-177.

Dillashaw, F. G., & Okey, J. R. (1980). Test of the integrated science process skills for secondary science students. Science Education, 64, 601-608.

Hecking, T., Manske, S., Bollen, L., Govaerts, S., Vozniuk, A., & Hoppe, U. (2014). A flexible and extendable learning analytics infrastructure. In: Proceedings of the 13th International Conference on Web-Based Learning (ICWL 2014, Tallinn, Estonia). Springer International Publishing.

Koslowski, B. (1996). Theory and Evidence: The Development of Scientific Reasoning. Cambridge, MA: MIT Press.

Möller, A., Hartmann, S., & Mayer, J. (2010). Differentiation and Development of Five Levels in Scientific Inquiry Skills: A Longitudinal Assessment of Biology Students in Grade 5 to 10. Paper presented at the meeting of the National Association for Research in Science Teaching (NARST). Philadelphia, USA, March 2010.

Njoo, M., & de Jong, T. (1993). Exploratory Learning with a Computer Simulation for Control Theory: Learning Processes and Instructional Support. Journal of Research in Science Teaching, 30, 821−844.

Pedaste, M., Mäeots, M., Siiman L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational Research Review, 14, 47−61.

Siiman L. A., Pedaste, M., Mäeots, M., Zacharia, Z. C., & de Jong, T. (2016). Design and Evaluation of an Online Inquiry Learning Space to Support Students' Conceptualization Inquiry Skills. Manuscript submitted for publication.

Sodian, B., Zaitchik, D., & Carey, S. (1991). Young Children's Differentiation of Hypothetical Beliefs from Evidence. Child Development, 62, 753−766.

van Joolingen, W. R., & de Jong, T. (1991). Supporting Hypothesis Generation by Learners Exploring an Interactive Computer Simulation. Instructional Science, 20, 389–404.

Vozniuk, A., Govaerts, S., & Gillet, D. (2013). Towards portable learning analytics dashboards. Proceedings of the International Conference on Advanced Learning Technologies (ICALT 2013, Beijing, Ching). IEEE Press.

1.2 Study 2: Scaffolding students' reflection in the Go-Lab learning environment

1.2.1 Abstract

Go-Lab deliverable D8.3 described a study (chapter 12, pp. 129-135) that evaluated the effect of a Go-Lab app called the Reflection Tool on students' reflections. Two aspects were assessed in students' reflections: content and level. Reflection content was coded as one of three categories: technical, situational and sensitising (Leijen et al., 2012; Poldner et al, 2014). Reflection levels were assessed based on the reflection levels developed by Poldner et al. (2014). Poldner et al. (2014) further elaborated four reflection levels that were developed by Leijen et al (2012) and created the following five levels: description (descriptions of the difficulties that the student had), justification (rationale or logical explanation for the difficulties), critique (explanation and evaluation of the difficulties), dialogue (critical review of different solutions or alternative methods), and transfer (how the next action becomes different or better than the previous action was). The results of the D8.3 study showed that students generated reflections at all levels. However, due to technical obstacles of a slow school internet connection not displaying the Reflection Tool optimally on student tablet computers, the Reflection Tool condition did not demonstrate statistically significant learning effect.

In this new study we aimed to identify the relation between students' reflection levels and their inquiry learning outcomes (i.e. their formulated conclusions) after conducting a complete inquiry cycle in an online Go-Lab Inquiry Learning Space (ILS). We expected that students exhibiting a higher reflection level would be more experienced in formulating higher quality conclusions than students at a lower reflection level. Forty-three students from the 9th grade with an average age of 15 years from two Estonian public schools participated in this study. A non-parametric Mann-Whitney U-test revealed that the students who formulated conclusions

at a high quality level also scored higher on the reflection level (Z=-2.574; p<0.01). The results suggest that students who reflect at a higher reflection level are more successful in formulating higher quality inquiry outcomes such as hypotheses, observations and conclusions. These results were presented at the EDULEARN 2016 conference:

> Mäeots, M., Siiman, L., Kori, K., & Pedaste, M. (2016). Relation between students' reflection levels and their inquiry learning outcomes. In Proceedings of the 8th annual International Conference on Education and New Learning Technologies (EDULEARN), pp. 5558−5564.

1.2.2 Introduction

Reflection is a cognitive process to learn from previous learning experience (Moon, 2004; Schön, 1983). It encourages learners at any age to analyse what they have done during the learning process (Goodman, Linton, & Gaimari, 2016). In order to achieve the best outcome of the reflection, then it has to be planned by the learner. But in the case of students at school it does not always occur spontaneously. It is mostly because students are not capable of reflecting on their learning without guidance (Kori, Pedaste, Leijen, & Mäeots, 2014). Research has shown that guided reflection helps students to achieve higher quality of reflection (Leijen, Valtna, Leijen, & Pedaste, 2012), and if reflective activities' are embedded into the learning task (i.e. into the inquiry learning task), then it might have larger effect on learning (Pedaste, Mäeots, Leijen, & Sarapuu, 2012). In the current study, reflection was supported with a Go-Lab app called the Reflection Tool (Mäeots, Siiman, Kori, Eelmets, Pedaste, Anjewierden, 2016), which was placed in the last inquiry phase (i.e. the Discussion phase) of an ILS called 'What does pH measure?'

The current study aimed to identify the relation between students' reflection levels and their formulated conclusions after conducting a complete inquiry cycle in an online Inquiry Learning Space (ILS). Taking into consideration the aim of the current study the following research questions were addressed:

- What is the quality of the students' reflections after conducting a complete inquiry cycle?
- What is the quality of the students' conclusions after conducting a complete inquiry cycle?
- What is the relation between students' reflections and formulated conclusions?

1.2.3 Method

Participants and Procedure

The sample consisted of 43 students (average age of 15 years) from two 9th grade classes at a public school in Estonia. The gender distribution among students was 21 female students and 22 male students. The intervention was one school lesson (45 minutes).

Materials

In the current study a chemistry topic ILS was designed called "What does pH measure?" based on the five phase inquiry cycle structure of Pedaste et al. (2015). The five phases in the ILS are Orientation, Conceptualization, Investigation, Conclusion and Discussion, and four Go-Lab inquiry apps were embedded in the ILS: a Hypothesis Scratchpad in the Conceptualization phase, an Observation Tool in the Investigation phase, a Conclusion Tool in the Conclusion phase, and a Reflection Tool in the Discussion phase. In the Orientation phase of the ILS, the chemistry topic of pH was introduced and two research questions posed to students: (1) What does pH measure? (2) How does the pH of an acidic or alkaline solution change when water is added to it? In the next phase, the Conceptualization phase, students were allowed to briefly interact with two virtual labs, “Acid-Base Solutions” and “pH Scale: Basics”, created by the PhET project (http://phet.colorado.edu), and then instructed to formulate two hypotheses related to the two research questions presented to them during the Orientation phase. In the Investigation phase students were able to thoroughly interact with the two virtual labs to conduct experiments and record observations to find evidence for confirming or rejecting their hypotheses. In the Conclusion phase students were instructed to compare their observations to their initial hypotheses and state evidence-based conclusions. In the final phase, the Discussion phase, students were asked two reflection questions: (1) “Which inquiry phase was the most difficult for you and why?” and (2) “What would you do differently the next time you conduct an inquiry investigation?”

Assessment

Students’ reflections and conclusions were analysed by two researchers using the rubrics shown in Table 2 and Table 3.

The quality of students’ conclusions was assessed by four criteria: consistency with hypotheses, presence of the dependent variable, presence of the independent variable, presence of a relation. The Cohen’s kappa between two researchers was 0.839.

Table 2. A rubric for assessing the level of students’ reflections.

Reflection level	Description of the level
Description	Descriptions of the difficulties that the student had.
Justification	Rationale or logical explanation for the difficulties.
Critique	Explanation and evaluation of the difficulties.
Dialogue	Critical review of different solutions or alternative methods.
Transfer	Transfer knowledge of how the next action becomes different or better than the previous action.

Table 3. A rubric for assessing the quality of students' conclusions.

Criteria	Description	Scoring
Consistency	The conclusion is consistent if it derives from the hypotheses formulated by the student in the Conceptualization phase and considers the experimental observation made in the Investigation phase.	0 points – conclusion is not consistent with the hypotheses. 1 point – conclusion is consistent with the hypotheses.
Dependent variable	Dependent variable results from the formulated hypotheses (e.g., amount of hydrogen ions in the solution).	0 points – dependent variable is missing. 1 point – dependent variable is present.
Independent variable	Independent variable results from the formulated hypotheses (e.g., pH level of the solution).	0 points – independent variable is missing. 1 point – independent variable is present.
Relation	Relation between independent and dependent variables is present and considers the experimental observation made in the Investigation phase (e.g., if the amount of the hydrogen ions increases, then the pH level of solution decreases).	0 points – relation is missing. 1 point – relation considers the hypotheses.

Results and discussion

The results of analysing students' reflection for the first reflective question resulted in 15 students being identified at the description level and 28 students at the justification level. Table 4 presents the distribution of students' reflection levels and corresponding examples.

Table 4. Distribution of students' reflection levels and examples of their work (N = 43).

Reflection level	Number of students	Examples
Description	15	"Experimenting was the most difficult for me." "Everything was difficult for me." "Making conclusions was the most difficult for me, but I do not know why."
Justification	28	"I had difficulties in the hypothesis generation phase because it took longer than expected." "Hypothesis formulation and conclusion making were the most difficult for me because I did not exactly understand how to formulate them." "For me the most difficult phase was investigation. I understood how teh experiment goes, but I met difficulties in writing my observations."

Disappointingly, the highest reflection levels (critique, dialogue and transfer) were not detected at all. The wording of the first reflective question contained the phrase "the most difficult" and immediately after asked students "why" it was the most difficult, but still 15 students mentioned only the name of the inquiry phase which was the most difficult for them without explaining why it was difficult for them. The most frequently named phases by the students (some students pointed out two phases) at the description and justification reflection level were Conceptualisation (mentioned 18 times) and the Investigation phase (mentioned 15 times).

Analysis of students' conclusions showed that most students were able to formulate conclusions that were consistent with the formulated hypotheses (74%), but sometimes they missed one or another component of the hypothesis (e.g., relation between independent and dependent variable). All of the students' conclusions contained a construct that can be classified as a dependent variable. In the case of nine students the dependent variable was the only component of the conclusion that could be detected. An independent variable could be identified 29 times and was always together with a dependent variable. But if we look at the presence of a relation between independent and dependent variables in the students' generated conclusions, then a relation between variables was stated only 22 times.

In order to study the relation between students' reflections and the conclusions they formulated, students were divided into two groups based on the quality of the conclusions. A non-parametric Mann-Whitney U-test revealed that the students who formulated conclusions at a high quality level also scored higher on the reflection level ($Z=-2.574$; $p<0.01$). A moderate correlation ($\rho=0.420$; $p<0.005$) was found between the quality of students' reflections and the consistency of their conclusions with their hypotheses. The results suggest that students who reflect at a higher reflection level are more successful in formulating high quality conclusions.

Conclusion

The current study aimed to identify the relation between students' reflection levels and their formulated conclusions after conducting a complete inquiry cycle in an online Inquiry Learning Space (ILS). Our results revealed that students show a rather low level of reflection quality (only the lower levels description and justification were detected). Students' reflections mostly considered formulation related, time-related and topic-related issues. The latter can be used as an input for creating suitable scaffolding for inquiry-based tasks. Also, students' reflected what they themselves would like to do differently next time when conducting inquiry-based activities. We detected four categories: time, inquiry phase, learning and topic. It is useful to note that students refer to the same difficulties that usually researchers indicate in their studies, and therefore shows these are critical issues that require attention. In addition to assessing students' reflections we analysed students' conclusions. The majority of the formulated conclusions were consistent with the initial hypotheses formulated by a student. Finally, we found a statistically significant difference between students who showed a high level of reflection and students who showed a low level of reflection when comparing the quality of the conclusions stated by these students. Therefore, it seems that reflection should be part of the learning process in order to support students in achieving higher quality inquiry learning outcomes.

References

Goodman, B., Linton, F., & Gaimari, R. (2016). Encouraging Student Reflection and Articulation Using a Learning Companion: A Commentary. International Journal of Artificial Intelligence In Education, 26(1), 474-488.

Kori, K., Pedaste, M., Leijen, Ä., & Mäeots, M. (2014). Review: Supporting reflection in technology-enhanced learning. Educational Research Review, 1145-55.

Leijen, Ä., Valtna, K., Leijen, D. A., & Pedaste, M. (2012). How to determine the quality of students' reflections? Studies in Higher Education, 37(2), 203-217.

Mäeots, M., Siiman, L., Kori, K., Eelmets, M., Pedaste, M., & Anjewierden, A. (2016). The role of a reflection tool in enhancing students' reflection. In Proceedings of the 10th International Technology, Education and Development Conference (INTED), pp. 1892−1900.

Mäeots, M., Siiman, L., Kori, K., & Pedaste, M. (2016). Relation between students' reflection levels and their inquiry learning outcomes. In Proceedings of the 8th annual International Conference on Education and New Learning Technologies (EDULEARN), pp. 5558−5564.

Moon, J. A. (2004). Reflection in learning and professional development. New York: Routledge.

Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, T. (2012). Improving students' inquiry skills through reflection and self-regulation scaffolds. Technology, Instruction, Cognition and Learning¸ 9, 81-95.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. T., & ... Tsourlidaki, E. (2015). Review: Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational Research Review, 14, 47-61.

Poldner, E., Simons, P. R. J., Wijngaards, G., & Van der Schaaf, M. F. (2012). Quantitative content analysis procedures to analyse students' reflective essays: A methodological review of psychometric and edumetric aspects. Educational Research Review, 7(1), 19-37.

Schön, D. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books.

1.3 Study 3: Is it better to reflect upon your experiment design?

1.3.1 Introduction

Educators prepare learners for the world, and need to make use of teaching methods that allow learners to acquire useful skills and knowledge. It has become increasingly important for people to gather, select and understand quality information, and to be able to construct their own knowledge. Learners perform better on examinations when they learn actively than when they attend lectures (Freeman et al., 2014). An effective learning method is guided inquiry learning, during which learners get acquainted with, and practice, inquiry skills and processes in order to gain knowledge about a domain by engaging in scientific investigations (Lazonder & Harmsen, 2016; Minner, Levy, & Century, 2010; Pedaste et al., 2015).

However, inquiry learning is complex and consists of many processes. Several inquiry phases have been specified by scholars, many of whom created their own inquiry cycle (e.g., White & Frederiksen, 1998). Pedaste et al. (2015) summarized these by creating an inquiry cycle based on the descriptions of the phases they found in their meta-analyses on inquiry cycles. They found that an inquiry learning activity typically involves one or several of the following phases: orientation, conceptualization, investigation, conclusion, and discussion. In the orientation phase the topic of investigation is explored by the learner. In order for learning through conducting inquiry to occur, it is crucial for the learner to have a basic understanding of the topic of investigation. If the learner does not have sufficient knowledge about the topic, it is very difficult or even impossible to formulate meaningful research questions and to design useful experiments (e.g., Quintana et al., 2004). In the conceptualization phase learners formulate research questions or hypotheses to investigate. During the investigation phase, which can be seen as one of the core phases, learners design and conduct experiments based on which they draw conclusions in the conclusion phase. The discussion phase, as described by Pedaste et al. (2015), can take place at the end of each previously described phase, or at the end of the entire inquiry. In this phase learners reflect upon their inquiries and communicate their findings.

In the current study we focus on the investigation phase which is at the core of the inquiry model of Pedaste et al. (2015) and serves as a bridge between the hypothesis or research question and the conclusion (Arnold, Kremer, & Mayer, 2014).

In designing experiments learners have to consider dependent, independent and control variables (Chinn & Malhotra, 2002; Klahr & Dunbar, 1988). It is important for them to understand that each variable that is not controlled for can influence the outcome of an experiment and thus to realize that only independent variables should be varied and all other variables should be controlled for. In addition, it is useful for learners to be familiar with strategies of choosing values for variables within an experiment design. Strategies that are often applied by professional scientists are the use of extreme values and equal increments between trials (Veermans, van Joolingen, & de Jong, 2006). Using extremely low or high values allows the exploration of the boundaries of a domain, and equal increments provides information about the strength of an effect of the independent variable on the dependent variable, and if and when this changes.

In addition to knowledge about designing experiments, learners should have prior knowledge about the domain of investigation in order to design useful experiments. Prior knowledge has found to be the most influential factor for learning and performance in general (e.g., Kalyuga, 2007). There is a positive correlation between learners' prior knowledge, and their gain of new conceptual knowledge as well as their ability to apply higher-order cognitive skills, like designing experiments (Hailikari, Katajavuori, & Lindblom-Ylanne, 2008). When learners are not familiar with skills such as designing experiments and in addition possess little prior knowledge, they are often confronted with too many new elements, which impedes the learning process (e.g., Hailikari et al., 2008; Kalyuga, 2007; Lazonder, Wilhelm, & Hagemans, 2008). Learners with little prior knowledge use less sophisticated strategies and need more experiments to reach conclusions than their more knowledgeable peers who employ more well-structured goal-oriented inquiry strategies (Alexander & Judy, 1988; Hmelo, Nagarajan, & Day, 2000; Schauble, Glaser, Raghavan, & Reiner, 1991).

However, even though high prior knowledge learners have an advantage over low prior knowledge, designing useful experiments is still considered to be very difficult for learners of all ages. Results obtained by means of experimentation should allow learners to draw conclusions for their research questions, but they tend to design experiments that have nothing to do with their research question or with which they cannot reach conclusions. Common mistakes in experiment designs are the use of variables that have no relation with the research question, leaving out relevant variables, varying too many variables at the same time, and not considering control variables (de Jong, 2006). Moreover, learners are often not familiar with fruitful strategies of assigning values to the variables, like using extreme values to explore the domain or using smaller increments between experimental trials around changes in experiment outcomes in order to pinpoint when an effect occurs. Considering these difficulties learners experience, it is not surprising that inquiry learning has found to be ineffective when learners are minimally guided (d'Angelo et al., 2014). Yet, guided inquiry learning has found to be effective for learning and even superior to other instructional methods provided that learners are properly guided (Hmelo-Silver, Duncan, & Chinn, 2007). Hmelo-Silver et al. (2007) suggest to stop debating about whether or not guided inquiry learning works, but instead focus on under what circumstances it works, for what kind of knowledge and skills, and what kind of support is needed for what population and learning goal.

Guidance allows learners to achieve tasks they could not have accomplished on their own (Zacharia et al., 2015). In computer-supported learning environments tools and scaffolds are amongst the most well-documented forms of guidance (Zacharia et al., 2015). They simplify or take over part of the task, allowing learners to gain higher-order skills (de Jong, 2006; Reiser, 2004; Simons & Klein, 2007). Quintana et al. (2004) developed a Scaffolding Design Framework with guidelines for designing effective scaffolds for learners´ inquiry learning. The framework is based on literature about the scientific processes learners are engaged in, difficulties learners experience in this, and ways in which tools can provide guidance to learners. Seven main guidelines are distinguished in the framework. First, tools should be adapted to learners' prior knowledge and use language that they understand. Second, tools should guide students in acquiring knowledge and skills about the discipline and its semantics. Third, tools should provide learners with representations they can inspect in different ways. Fourth, tools should provide learners with a clear structure of the task to help them learn about relevant steps they can or need to take in order to accomplish the task. Fifth, tools should embed expert guidance to help them understand and employ useful strategies. Sixth, tools should automatically handle routine tasks that may distract them from learning. Seventh, tools should encourage learners to articulate and reflect upon their learning. Based on this Scaffolding Design Framework we designed the Experiment Design Tool, one type of guidance in the current study of which we studied the effect on gain of conceptual knowledge. This tool supports learners in designing their experiments and is further explained in the Method section.

In addition to guidance in the form of an Experiment Design Tool, we included a condition in which learners have to reflect on their designed and conducted experiments. In inquiry learning, the goal of designing and conducting experiments is to gain knowledge and/or skills, which requires learners to differentiate, integrate, and restructure ideas. Reflecting on original ideas, obtained experiment results, and relationships between original ideas and results can help learners to successfully process all the information and build a coherent understanding (Linn, Eylon, Rafferty, & Vitale, 2015) based on which they can revise their experimentation strategies and develop more effective strategies to design experiments and handle future activities (Davis, 2000; Linn et al., 2015; Pedaste et al., 2015). Generally, learners produce better products when they reflect upon their activities (Davis, 2000), but the quality of the products is strongly related to the quality of the reflection (Pedaste et al., 2015). In order to increase the quality of learners' reflections they can be prompted to evaluate their experiment designs based on a carefully chosen set of heuristics for experiment design (Kori, Mäeots, & Pedaste, 2014; White & Frederiksen, 1998)

1.3.2 Method

The current study focused on the effect of different types of guidance for designing and conducting experiments on students' gain of knowledge about buoyancy and Archimedes' principle. Three conditions were compared, each of which entailed third-year pre-university students (approximate age: 15 years) who worked in an online inquiry learning environment.

1.3.3 Participants

A total of 167 third grade pre-university students (approximate age: 15 years) participated in the current study. After removing outliers and students who missed a session, a total of 138 students were taken into account for analyses. All students had already learned about buoyancy within regular science classes, but the topic of Archimedes' principle was new to them.

1.3.4 Learning environments

Students in all conditions worked in an online inquiry learning environment revolving around buoyancy and Archimedes' principle (Figure 9). The environments consisted of three types of tabs: a method tab, orientation tabs, and experiment tabs. In the method tab information was provided about the kind and purpose of activities students were going to do, how they could perform those activities, and how they should navigate through the learning environment. In the orientation tabs materials like texts, images and videos, were presented to help students acquire or activate (prior) knowledge about buoyancy and Archimedes' principle in order for them to be able to successfully design experiments, which they could do in the experiment tabs. Each experiment tab consisted of a research question, a tool in which students could design their experiments, an online laboratory called Splash, and a conclusion textbox. Students were explicitly told to carefully read the research question and design experiments with which they thought they could answer the research question. Designed experiments were automatically transferred to the lab, but students still had to note down the results. They were encouraged to design and conduct as many experiments as necessary to be able to draw a conclusion.

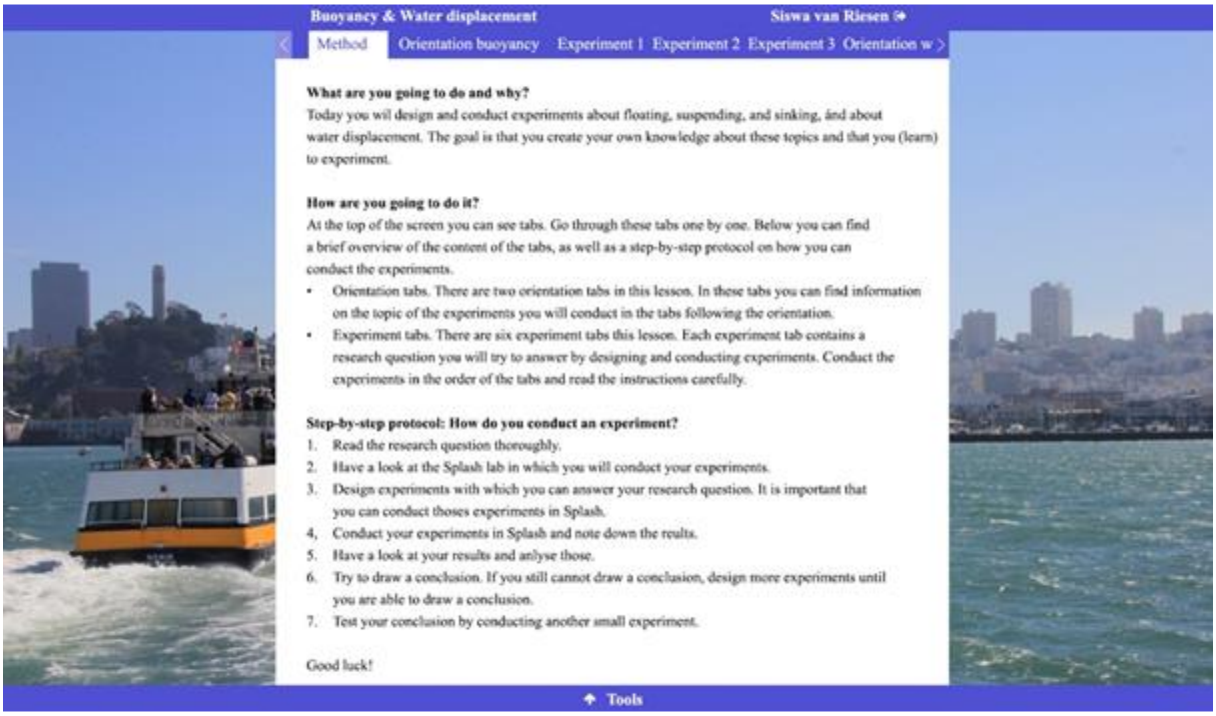


Figure 9. ILS on Archimedes' principle.

Each condition had its own learning environment. The learning environments only differed in the guidance for designing experiments and the texts related to that. In the section Experiment Design the guidance students received in the different conditions is described.

Online virtual lab: Splash

Splash is a virtual laboratory about buoyancy and Archimedes' principle (Figure 10). In Splash several fluid-filled tubes are depicted in which balls can be dropped. Learners could manipulate the density of the fluids in the tubes, as well as the mass, volume and density of the balls. Because mass divided by volume equals density, only two of these variables could be specified by the user and the third one was automatically calculated by Splash.

After the student had designed the balls and had chosen the density of the fluid, they could drop the balls in the tubes and observe whether the balls sank, suspended, or floated in the fluids. In labs about Archimedes' principle learners could additionally observe the mass and volume of the displaced fluid, as well as the forces in the domain of Archimedes' principle.

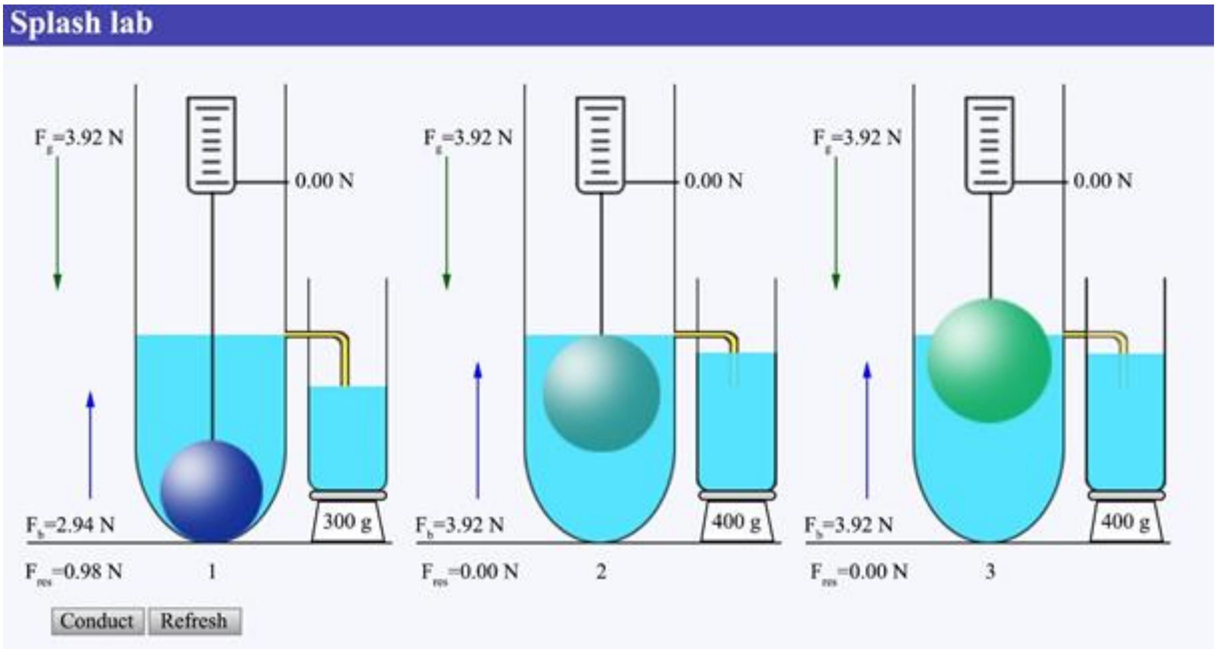


Figure 10. Online Virtual Lab: Splash.

1.3.5 Experiment design

The three conditions contained differed tools that provided students with guidance for designing their experiments, as described in this section. The Experiment Design Tool was used in the EDT condition and in the EDT + reflection condition, the Reflection tool was only used in the EDT + reflection condition in addition to the EDT, and a simplified version of the EDT was used in the control condition.

Experiment Design Tool

In the EDT condition and the EDT+ reflection condition students designed their experiments with the Experiment Tool (Figure 11). The EDT presented students with a predefined list of variables that were related to buoyancy or Archimedes' principle and that were relevant for the experiments students had to design in order to be able to answer research questions. For each variable students could decide to vary it (independent variable), keep it constant (controlled variable), or measure it (dependent variable). As shown in Figure 11, students could select a variable from the list and drag and drop it to one of the boxes "vary", "keep constant", or "measure". For each independent variable they could choose one value per experimental trial, and for each controlled variable they had to select one value that was automatically assigned to all trials within an experiment. Students could only choose values within a given range in order to restrict their choices. Because density, which equals mass divided by volume, is important for students to understand the EDT provided students with the density calculated based on values students had chosen for mass and volume. The final column "measure" allowed students to enter the results they obtained after they had conducted their experimental trials. It should be noted that the trials students had designed in the EDT were automatically transferred to the lab.

At any time, students could view all their previously designed and conducted experimental trials by pressing the table icon (Figure 11, top left). In that table they could sort their data per variable in ascending or descending order, making it easier to compare trials.

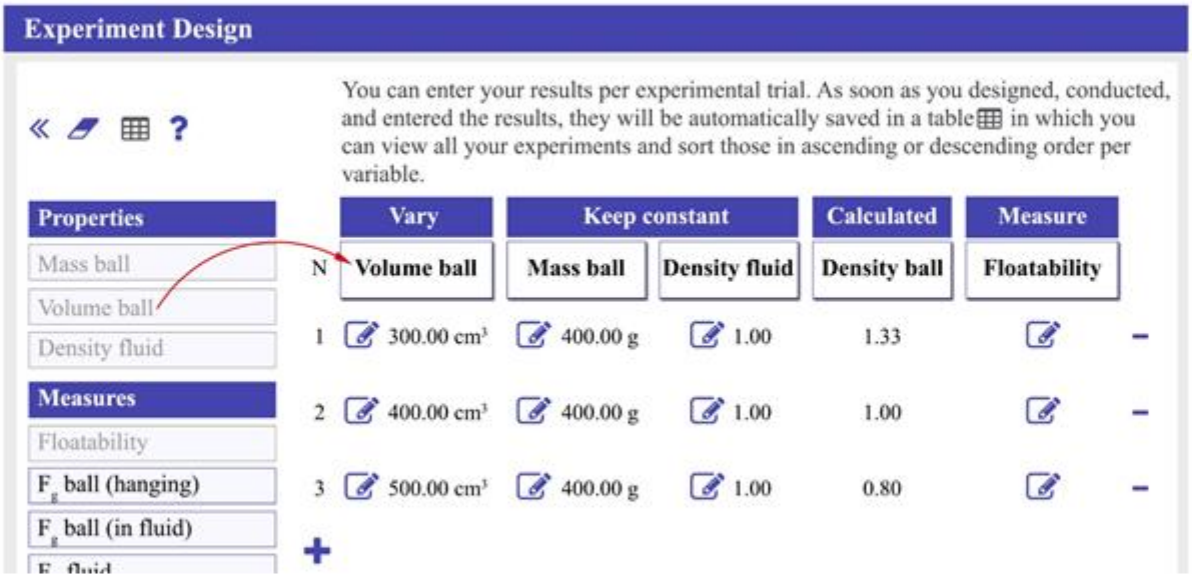


Figure 11. The Experiment Tool.

Reflection questions for the reflection condition

In addition to designing their experiments in the EDT, students in the EDT + reflection condition also had to use a Reflection tool to reflect on each experiment they designed. Before students could start reflecting on an experiment they had to have designed and conducted at least three trials. The reflection questions students had to answer were based on their experiment design and the answers they gave in the Reflection tool. For example, they were first asked if they conducted correct and a sufficient number of experiments in order to be able to answer the research question completely. If they indicated that they did, the Reflection tool used information about the number of varied variables to ask students to write down why they varied one, or more, variables in their experiment. If they had varied just one variable, the tool asked students why they had chosen to assign 1) extreme values, 2) values that have the same increment between trials, 3) values within a small range, or 4) another strategy. The strategy students had to reflect on, was again based on their designed experiment. After they wrote down their response, they could enter their conclusion on the research question. Figure 12 shows the flowchart of reflection questions students had to answer. Please note that students had to continue designing and conducting experiments, and reflecting upon their experiments until they reached the conclusion input box.

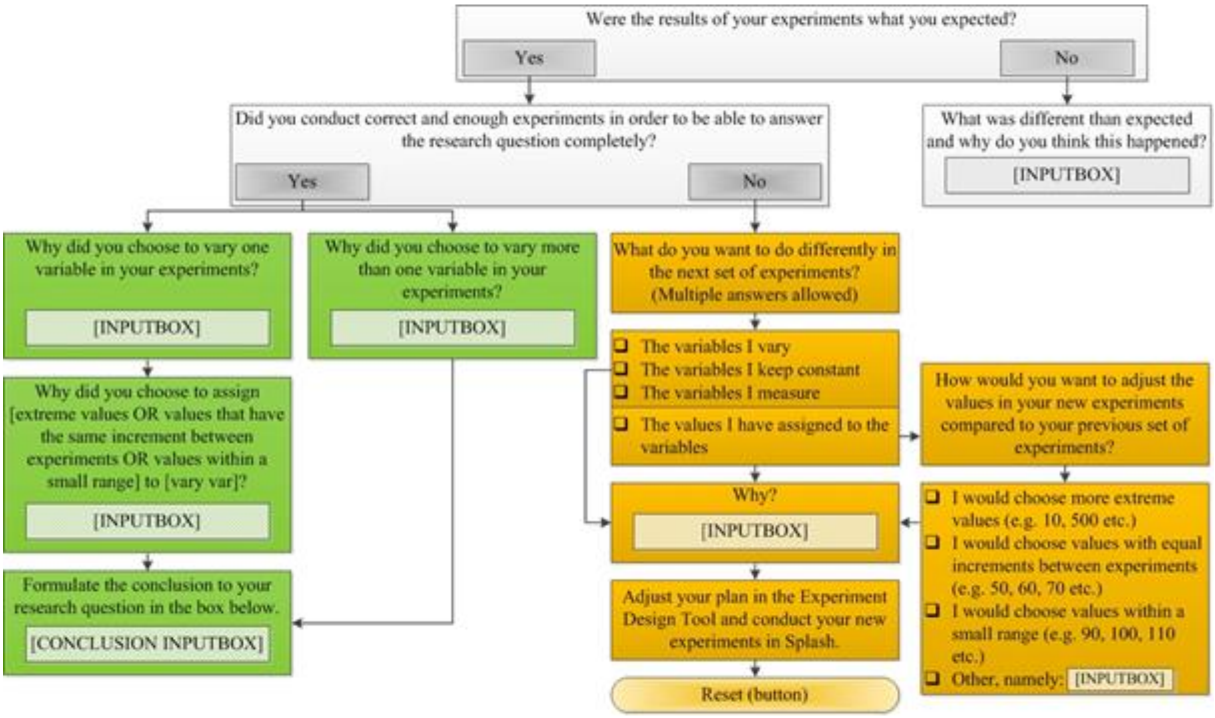


Figure 12. Flowchart reflection questions.

Tool in the control condition

In the control condition students had to design their experiments using a simplified version of the Experiment Design Tool (Figure 11). The only difference with the EDT is that simplified EDT did not make a distinction between independent and control variables. Instead, students could simply drag variables into the table and assign a value to each variable in each trial, thereby increasing the possibility to design unstructured experiments. Because the designed trials were sent to Splash, entailing that Splash should be able to digest the designed trials, the simplified EDT provided students with the same variables as the EDT, as well as an identical range of values to assign to the variables.

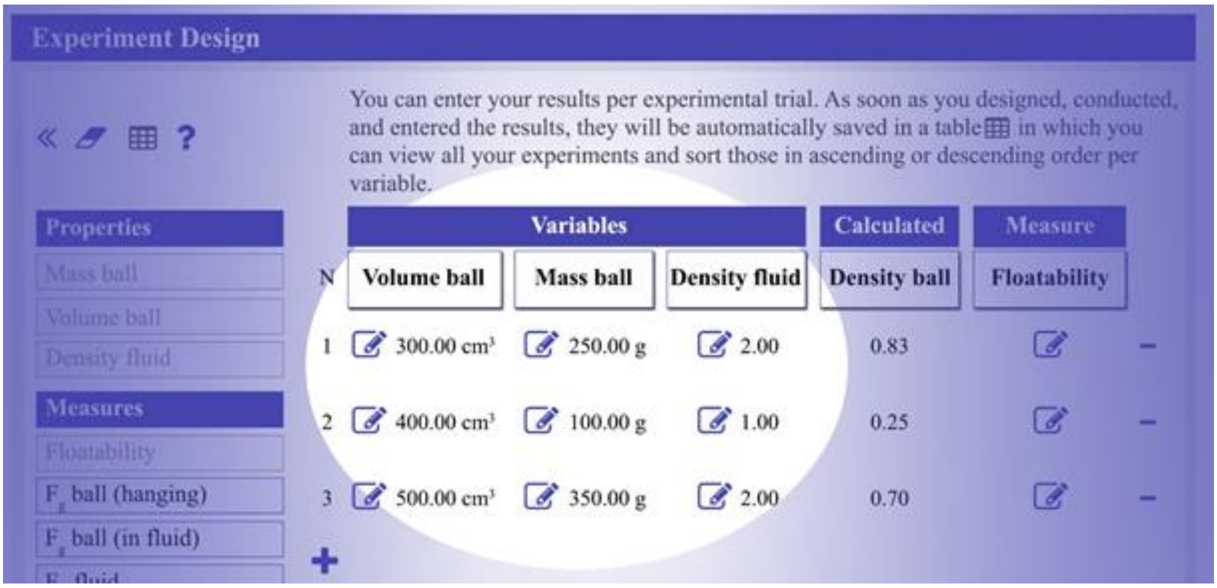


Figure 13. The tool in the control condition.

1.3.6 Assessment

In the current study we assessed students' knowledge about buoyancy and Archimedes' principle with a parallel pre- and post-test that was taken from the study described in Annex 5. The test was specifically created to assess students' knowledge after working with Splash and contained a total of 25 open questions about buoyancy and 33 open questions about Archimedes' principle, for which they could obtain a total of 58 points. In the current study Cronbach's Alpha's were, for the pre-test about buoyancy .933 and about Archimedes' principle .893, and for the post-test about buoyancy.898 and Archimedes' principle of .910 based the 147 students who were part of the analyses.

1.3.7 Procedure

The study entailed four sessions of 45-50 minutes each, that all took place within a timeframe of two and a half weeks. Students' prior knowledge about buoyancy and Archimedes' principle was measured with a pen-and-paper pre-test during the first session. They were given thirty minutes to complete the test, which was sufficient for all of them to finish. After the test, students were placed in their condition; they were assigned to a condition based on their physics report mark to create three comparable conditions. The remaining time was used to instruct students within their condition on how to work with the learning environment. During the second session students worked with the learning environment about buoyancy and water displacement. As explained to them in the first session, they had to individually design and conduct experiments on the computer in order to gain knowledge and to acquire experimentation skills. At the start of the session they were encouraged to read the research questions very carefully in order to design useful experiments to draw conclusions. All necessary prior domain information could be found in the learning environment, as well as instructions they had already received orally in the first session. During the third session students also worked with the learning environment, but the topics of experimentation were forces within the domain of Archimedes' principle, and again water displacement. The part about water displacement was identical to that part in the previous session, but was added for students who had not yet completed all their experiments yet. In the fourth session students had half an hour to complete the post-test about buoyancy and Archimedes' principle, and finally the subject matter was discussed.

1.3.8 Results

In the current study students designed and conducted experiments to learn about buoyancy and Archimedes' principle. Three conditions were compared with regard to students' learning gain about buoyancy and Archimedes' principle. First, we analyzed if students had learned from working with the learning environments, and if there was a difference between conditions. A one-way repeated measures ANOVA with the pre- and post-test as time measures showed a significant learning gain for buoyancy, $F(1,144) = 65{,}62$, $p < .0005$; Wilk's $\Lambda = 0.687$, partial $\eta 2 = .31$, and for Archimedes' principle, $F(1, 144) = 119.82$, $p < .0005$; Wilk's $\Lambda = 0.546$, partial $\eta 2 = .45$. No significant differences were found between conditions for both buoyancy, $F(2, 144) = 0{,}20$, $p = .822$; Wilk's $\Lambda = 0.997$, partial $\eta 2 = .003$, and Archimedes' principle, $F(2, 144) = 0{,}33$, $p = .718$; Wilk's $\Lambda = 0.995$, partial $\eta 2 = .005$. Table 5 shows the mean scores and the standard deviations on the pre- and post-test.

Table 5. Descriptive statistics for test scores by condition.

	EDT (N=52)		*EDT+ (N=48)*		*Control (N=47)*		*Total (N=147)*	
Test	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Buoyancy (max=25)								
Pre-test	16.04	7.31	15.40	7.78	17.28	6.93	16.22	7.34
Post-test	20.69	4.16	19.54	6.27	21.15	4.79	20.46	5.14
Difference score	4.65	6.92	4.15	5.66	3.87	6.24	4.24	6.28
Archimedes' principle (max=33)								
Pre-test	7.33	6.66	7.15	5.36	7.45	5.56	7.31	5.88
Post-test	13.71	8.59	12.77	6.92	12.83	6.88	13.12	7.50
Difference score	6.38	6.25	5.63	7.24	5.38	5.65	5.82	6.39

Our second main interest was the effect of prior knowledge on students' need for different levels and forms of support for designing experiments. Based on their pre-test scores, students were classified as novices, beginners, advanced learners, or experts. Table 6 shows the classification of students based on their prior knowledge. Please, note that students were classified as a type of learner for buoyancy and Archimedes' principle separately, meaning that they could, for example, be an expert in buoyancy but a novice in Archimedes' principle.

Table 6. Classification of students based on their prior knowledge.

Type of learner	Pre-test buoyancy	Pre-test Archimedes' principle
Novice	0-6 correct	0-8 correct
Beginner	7-12 correct	9-16 correct
Advanced learner	13-18 correct	17-24 correct
Expert	19-25 correct	25-33 correct

For each type of learner, an independent samples Kruskal-Wallis test was performed for buoyancy. No significant differences were found between conditions, meaning that the conditions all worked equally for all groups of students for the buoyancy subdomain.

Independent samples Kruskal-Wallis tests for Archimedes' principle only showed a significant difference between conditions for low-intermediate prior knowledge students, $H(2) = 6.20$, $p = .045$. Table 7 shows the means and standard deviations of the pre- and post-test scores, as well as difference scores, about Archimedes' principle for this group. Follow-up Mann-Whitney analyses showed significant differences between the EDT condition and the control condition, ($U = 153.00$, $p = .037$), as well as between the EDT condition and the EDT + reflection condition, ($U = 69.50$, $p = .027$), both in favor of the EDT condition.

Table 7. Test scores of students with low-intermediate prior knowledge about Archimedes' principle.

	EDT (n=15)		*EDT+ (n=17)*		*Control (n=14)*		*Total (n=46)*	
Test	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pre-test (max=33)	11.60	1.99	11.94	2.30	12.57	3.11	12.02	2.46
Post-test (max=33)	20.27	5.75	16.35	5.45	16.42	5.75	17.82	5.81
Difference score	8.67	4.98	4.41	5.26	3.86	5.76	5.63	5.63

1.3.9 Conclusion and discussion

In the current study third grade secondary students designed and conducted experiments in an online lab to learn about buoyancy and Archimedes' principle. Three types of support were compared in terms of students' gain of conceptual knowledge. Overall, no differences were found between conditions. However, when we took prior knowledge into account, we found a significant difference between conditions for low-intermediate prior knowledge students (who had 26-50% correct on the pre-test about Archimedes' principle) about Archimedes' principle. Post-hoc Mann-Whitney analyses showed that students who worked with just the Experiment Design Tool had an increase in score from pre- to post-test that was almost double the increase of students in both other conditions. This outcome was partly unexpected, considering that 1) low-intermediate prior students who worked with exactly the same tool but additionally had to reflect upon their experiments gained less knowledge than students who did not have to reflect, and 2) no significant differences were found between conditions for low prior knowledge students.

Amongst scholars, there is a general consensus that low prior knowledge students benefit from additional guidance (Kalyuga & Renkl, 2009). Guidance can act as a substitute for knowledge and skills that are required to accomplish a task (Tuovinen & Sweller, 1999). Results of the current study partly support this, but only for low-intermediate prior knowledge students; low-intermediate prior knowledge students using the Experiment Design Tool without having to reflect upon their experiments performed better than low-intermediate prior knowledge students in the control condition who used a simplified version of the Experiment Design Tool. In the EDT a clear distinction is made between independent and control variables, encouraging learners who worked with this tool to consider control variables and design more structured experiments. In contrast, students in the control condition had to think about controlling variables on their own, and thus had to be aware of the advantages of designing more structured experiments. Arnold et al. (2014) analyzed difficulties students (aged 16-19) encountered in designing experiments, and found that 75% of the students failed to consider control variables. They suggested to support students in this by showing them how they could control variables, which is exactly what the Experiment Design Tool does.

The first surprising outcome of the current study was that low-intermediate prior knowledge students who worked with the Experiment Design Tool but who also reflected upon their experiments, showed increases in score from pre- to post-test that were lower than students who did not have to reflect upon their experiments and comparable to students in the control condition. This outcome was unexpected since a large body of research has demonstrated the importance and advantages of reflection for successful learning. Reflection can lead to deeper learning, help learners integrate new and existing knowledge, and it allows them to gain more complex knowledge (Kori et al., 2014). However, reflection has also found to be difficult and is considered to be a task by itself. In the current study, considering the already difficult processes involved in designing experiments and their limited prior knowledge about the subject matter, the additional task of reflection added even more workload which may have limited students' conceptual knowledge gain.

The second unexpected outcome was that we only found a significant difference between conditions for low-intermediate prior knowledge students and not for low prior knowledge students. A fair share of scholars have found that learners with low prior knowledge benefit from higher levels of support (Lazonder et al., 2008), based on which we expected that low prior knowledge students would benefit the most, and high prior knowledge students the least, from additional support for designing experiments in terms of knowledge gain, but this was not supported by our data. We hypothesize that learners need to possess at least some prior knowledge, or time to gain this knowledge, in order for them to benefit from supporting tools in online learning environments. In the current study learners were provided with materials with which they could orient themselves on the topic of investigation, but familiarizing themselves with the topic meant that they could spend less time on their experiments. Within one session low prior knowledge students had to acquire the required prior domain knowledge, and in addition had to apply this knowledge by designing and conducting useful experiments from which they could extract knowledge. Alternatively, they could skip the step of familiarizing with the subject matter, and start designing and conducting experiments immediately, which is rather difficult or even impossible without the necessary prior knowledge. In both scenarios low prior knowledge students had to spend more time to learn about the subject matter than their more knowledgeable peers. In addition to this, low prior knowledge learners have found to apply less sophisticated strategies and require more trials to reach conclusions than learners with more prior knowledge (Alexander & Judy, 1988; Klahr & Dunbar, 1988). The obvious difficulties low prior knowledge students can experience may have prevented them from utilizing the offered additional support to their benefit.

The current study provided us with interesting information about the relationship between learners' prior knowledge and guidance for designing experiments to gain conceptual knowledge, but also left us with some unanswered questions that we are trying to find the answers to. We are particularly interested in similarities and differences in experimentation behaviour between students with different levels of prior knowledge, and the relationship between experimentation behaviours and how well students performed on the conceptual knowledge test. Currently we are working on unravelling log files of students with different levels of prior knowledge. In these log files, all their designed experiments are documented, as well as their conclusions on the research questions. Through an iterative process a coding scheme is being created to analyse students' use and order of applied experimentation strategies, as well as their conclusions. Strategies we are especially interested in are, amongst others, vary one thing at a time, extreme values, (equal) increments, and random values. Once we analysed students' conclusions on the research questions and the strategies they applied in designing experiments, their experimentation behaviours will be compared to their results on the conceptual knowledge test.

1.3.10 References

Alexander, P. A., & Judy, J. E. (1988). The interaction of domain-specific and strategic knowledge in academic performance. *Review of Educational Research, 58*, 375-404. doi:10.3102/00346543058004375

Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding students' experiments - What kind of support do they need in inquiry tasks? *International Journal of Science Education, 36*, 2719-2749. doi:10.1080/09500693.2014.93.0209

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175-218. doi:10.1002/sce.10001

d'Angelo, C., Rutstein, D., Harris, C., Bernard, R., Borokhovski, E., & Haertel, G. (2014). *Simulations for STEM Learning: Systematic review and meta-analysis*. Menlo Park, CA: SRI International.

Davis, E. A. (2000). Scaffolding students' knowledge integration: prompts for reflection in KIE. *International Journal of Science Education, 22*, 819-837. doi:10.1080/095006900412293

de Jong, T. (2006). Technological advances in inquiry learning. *Science, 312*, 532-533. doi:10.1126/science.1127750

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). *Active learning increases student performance in science, engineering, and mathematics.* Paper presented at the Proceedings of the National Academy of Sciences.

Hailikari, T., Katajavuori, N., & Lindblom-Ylanne, S. (2008). The relevance of prior knowledge in learning and instructional design. *American Journal of Pharmaceutical Education, 72*, Article 113. doi:10.5688/aj7205113

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*, 99-107. doi:10.1080/00461520701263368

Hmelo, C. E., Nagarajan, A., & Day, R. S. (2000). Effects of high and low prior knowledge on construction of a joint problem space. *The Journal of Experimental Education, 69*, 36-56. doi:10.1080/00220970009600648

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*, 509-539. doi:10.1007/s10648-007-9054-3

Kalyuga, S., & Renkl, A. (2009). Expertise reversal effect and its instructional implications: Introduction to the special issue. *Instructional Science, 38*, 209-215. doi:10.1007/s11251-009-9102-0

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science, 12*, 1-48. doi:10.1207/s15516709cog1201_1

Kori, K., Mäeots, M., & Pedaste, M. (2014). Guided reflection to support quality of reflection and inquiry in web-based learning. *Procedia - Social and Behavioral Sciences, 112*, 242-251. doi:10.1016/j.sbspro.2014.01.1161

Lazonder, A., W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research, 86*, 681-718. doi:10.3102/0034654315627366

Lazonder, A., W., Wilhelm, P., & Hagemans, M. G. (2008). The influence of domain knowledge on strategy use during simulation-based inquiry learning. *Learning and Instruction, 18*, 580-592. doi:10.1016/j.learninstruc.2007.12.001

Linn, M. C., Eylon, B. S., Rafferty, A., & Vitale, J. M. (2015). Designing instruction to improve lifelong inquiry learning. *Eurasia Journal of Mathematics, Science & Technology Education, 11*, 217-225. doi:10.12973/eurasia.2015.1317a

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction: What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*, 474-496. doi:10.1002/Tea.20347

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phase of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. doi:10.1016/j.edurev.2015.02.003

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., . . . Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences, 13*, 337-386. doi:10.1207/s15327809jls1303_4

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences, 13*, 273-304. doi:10.1207/s15327809jls1303_2

Schauble, L., Glaser, R., Raghavan, K., & Reiner, M. (1991). Causal models and experimentation strategies in scientific reasoning. *Journal of the Learning Sciences, 1*, 201-238. doi:10.1207/s15327809jls0102_3

Simons, K. D., & Klein, J. D. (2007). The impact of scaffolding and student achievement levels in a problem-based learning environment. *Instructional Science, 35*, 41-72. doi:10.1007/s11251-006-9002-5

Tuovinen, J. E., & Sweller, J. (1999). A comparison of cognitive load associated with discovery learning and worked examples. *Journal of Educational Psychology, 91*, 334-341. doi:10.1037/0022-0663.91.2.334

Veermans, K., van Joolingen, W. R., & de Jong, T. (2006). Use of heuristics to facilitate scientific discovery learning in a simulation learning environment in a physics domain. *International Journal of Science Education, 28*, 341-361. doi:10.1080/09500690500277615

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*, 3-118. doi:10.1207/s1532690xci1601_2

Zacharia, Z. C., Manoli, C., Xenofontos, N., de Jong, T., Pedaste, M., van Riesen, S. A. N., . . . Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Educational Technology Research and Development, 63*, 257-302. doi:10.1007/s11423-015-9370-0

1.4 Common Study 1: How many words are enough? Assessing three different configurations of the Hypothesis Scratchpad.

[This study is an extension of Chapter 4 (How many words are enough? Assessing three different configurations of the Hypothesis Scratchpad) of Deliverable D8.3 (First trial report)]

1.4.1 Abstract

The current study presents an extension of Chapter 4 (How many words are enough? Assessing three different configurations of the Hypothesis Scratchpad) of Deliverable D8.3 (First trial report). Additional data analyses were conducted to examine in more depth the effect of three different configurations of the Hypothesis Scratchpad on students' knowledge and inquiry skills. A further was top investigate whether there was any indication of intercontextual transfer of inquiry skills. Additional data analyses on the Hypothesis Scratchpad revealed that some degree of software scaffolding is needed to support the formulation of hypotheses. However, partial scaffolding might be more preferable than full scaffolding in the targeted skill, especially in terms of addressing saturation effects. Another major finding was that intercontextual transfer of skills, was mediated by metacognitive processes.

1.4.1.1 Introduction

There have been a series of research results that have indicated that problematizing scaffolds (i.e., that challenge students to pay attention to aspects of the learning task that might be otherwise overlooked; see Reiser, 2004; Molenaar et al. 2010) might invoke better learning results as compared to structuring scaffolds (i.e., that offer structure to a task and aim at decreasing task-complexity). For instance, problematizing scaffolds exceeded their structuring counterparts in the promotion of metacognitive skills (De Backer et al., 2016). Moreover, problematizing scaffolds fostered transfer of domain knowledge (Molenaar et al., 2011).

The Hypothesis Scratchpad is a scaffold developed in the frame of Go-Lab which allows for a deliberate exploration of the controversy between structuring learning tasks, on the one hand, and problematizing student inquiry, on the other. Varying the number of words (e.g., variables and conditionals) provided to students, one can vary the configuration of the tool between a structuring and a problematizing extreme. Providing all words needed to formulate a valid hypothesis would coincide with the structuring extreme, while offering no words would equate to offering no scaffold at all.

The current study presents an extension of Chapter 4 (How many words are enough? Assessing three different configurations of the Hypothesis Scratchpad) of Deliverable D8.3 (First trial report) and concentrates on the following research questions:

1. What is the effect of three different configurations of the Hypothesis Scratchpad, which differ in the number of words needed to form a hypothesis, on students' knowledge and inquiry skills?
2. Is there any indication that the tool might reinforce intercontextual transfer of inquiry skills?

1.4.2 Synopsis of methods

[(for a detailed account of the learning environment and instruments: Deliverable D8.3 (First trial report); Chapter 4 (How many words are enough? Assessing three different configurations of the Hypothesis Scratchpad)]

Out of 312 secondary school students (12-14 years old) who were included in data analyses for this extension of Common Study 1, 113 were excluded due to incomplete data. The final sample included 199 students (UT; UTE; UCY) divided in three conditions that referred to three different configurations of the Hypothesis Scratchpad (Condition 1: all words, 69 students; Condition 2: some words, 63 students; Condition 3: no words, 67 students). Students went through an ILS, where the Splash-Lab was embedded. They completed knowledge and inquiry skill pre- and post-tests ("Remember"; "Understand"; "Apply" dimensions included in the knowledge test; "Identify variables"; "Formulate hypotheses" dimensions included in the skill test) and they also formulated their hypotheses in the Hypothesis Scratchpad (student hypotheses scored by means of a rubric developed for the sink-float context of our study (Figure 1); for each student, the hypothesis with the highest score was selected for data analyses. There was no difference among conditions in any dimension of the pre-tests. A new context for hypotheses formulation was given to 166 students ("submarine" context; UTE students not included), after the completion of the ILS (Condition 1: all words, 57 students; Condition 2: some words, 54 students; Condition 3: no words, 55 students). Statistical analyses involved non-parametric tests (Chi-Squate tests; Kruskal-Wallis tests; Mann-Whitney tests; Wilcoxon Signed Rank tests), computation of non-parametric correlations (Spearman's rho correlations), and logistic regression analyses. A first round of analyses was conducted for the entire sample and a second round focused on each country, separately, in order to validate data trends (convergent replication).

1.4.3 Results

First research question

What is the effect of three different configurations of a hypothesis formulation tool, which differ in the number of words needed to form a hypothesis, on students' knowledge and inquiry skills?

Pre-test and post-test scores for all conditions and knowledge and skill dimensions are presented in Table 8. We can observe that standard deviations were higher than average values for all knowledge dimensions in both pre-test and post-test scores, apart from the post-test scores for "Apply". Overall, average values were higher in skill dimensions as compared to knowledge dimensions. There were significant differences among conditions in post-test scores for skill dimensions, only. Specifically, Condition 1 scored higher than Condition 2 in "Identify variables" (Mann-Whitney $Z = -2.95$; $p < 0.01$), while Condition 1 scored higher than Condition 3 in "Formulate hypotheses" (Mann-Whitney $Z = -2.70$; $p < 0.01$).

We subtracted pre-test scores from post-test scores to derive emergent variables that corresponded to changes in knowledge and skills after the intervention (

Table 9). Any gains would be signified by positive values. “Remember” and “Understand”, among knowledge dimensions, as well as “Identify variables”, among skill dimensions, remained practically unchanged (please note that the negative means that emerged in two instances have a minimal absolute value and that has to be attributed to the fact that a number of students scored lower in the post test).

Table 8. Mean pre- and post-test scores in knowledge and skill dimensions across conditions.

	Condition 1	Condition 2	Condition 3	Kruskal Wallis χ^2
Pre-test scores				
Knowledge dimensions				
“Remember”	0.09 (0.28)	0.03 (0.18)	0.06 (0.24)	1.76ns
“Understand”	0.23 (0.43)	0.17 (0.38)	0.28 (0.45)	2.16ns
“Apply”	0.35 (0.37)	0.40 (0.38)	0.29 (0.32)	2.58ns
Skill dimensions				
“Identify variables”	0.40 (0.18)	0.37 (0.16)	0.37 (0.18)	1.44ns
“Formulate hypotheses”	0.43 (0.20)	0.37 (0.18)	0.42 (0.18)	2.71ns
Post-test scores				
Knowledge dimensions				
“Remember”	0.06 (0.24)	0.10 (0.30)	0.15 (0.36)	3.15ns
“Understand”	0.26 (0.44)	0.22 (0.42)	0.25 (0.44)	0.29ns
“Apply”	0.50 (0.40)	0.49 (0.36)	0.39 (0.35)	3.27ns
Skill dimensions				
“Identify variables”	0.47 (0.20)	0.37 (0.17)	0.43 (0.20)	8.89*
“Formulate hypotheses”	0.56 (0.19)	0.50 (0.21)	0.46 (0.20)	7.29*

Note: All dimensions were rescaled to range between 0 and 1; apart from pre-test scores for “Identify variables” (maximum score = 0.78) and “Formulate hypotheses” (maximum score = 0.89), all other maximum scores reached 1; standard deviations are given in parentheses; ns = non-significant; * $p < 0.05$.

Table 9. Average change in knowledge and skill dimensions after the intervention.

	Condition 1	Condition 2	Condition 3	Kruskal Wallis χ^2
Knowledge dimensions				
“Remember”	-0.03	0.06	0.09	4.08ns
“Understand”	0.03	0.05	-0.03	0.63ns
“Apply”	0.15	0.09	0.10	1.31ns
Skill dimensions				
“Identify variables”	0.07	0.00	0.06	4.63ns
“Formulate hypotheses”	0.12	0.13	0.03	9.69**

Note: ns = non-significant; ** $p < 0.01$.

There was a noteworthy improvement in “Apply” (knowledge dimension) and “Formulate hypotheses” (skill dimension) but only the latter differed significantly among conditions (Kruskal-Wallis Chi-square = 9.69; $p < 0.01$). In this case, conditions 1 and 2 improved more than condition 3 (Mann-Whitney Z = -2.37; $p < 0.05$, and Mann-Whitney Z = -2.95; $p < 0.01$ for condition 1 and 2, respectively). These results imply that the effect of varying degrees of software scaffolding was manifested on the targeted skill (“Formulate hypotheses”). Indeed, no scaffolding at all (Condition 3; no words) did not add to the targeted skill, while the task of formulating hypotheses seems to have been equally advanced through either full (Condition 1; all words) or partial (Condition 2; some words) scaffolding. Our results also indicate that software scaffolding facilitated metacognitive processes (“Apply”).

For each condition and knowledge or skill dimension, we also conducted Wilcoxon Signed Ranks Tests (Table 10). Conditions 1 and 3 improved in “Apply” and “Identify variables”, whereas Condition 2 did not. It seems that either full or no scaffolding might be associated with learning gains in identifying variables. For the full scaffolded condition, this might be readily attributed to the variables provided in the Hypothesis Scratchpad. When no words are given (no scaffolding provided), then students might be, once again, challenged to identify variables, the reasoning in this latter case might have been quite different, though. Namely, full scaffolding might facilitate variable identification through structuring student work (i.e., offering a fully-fledged scaffolding opportunity), while the condition where scaffolding is absent might problematize student inquiry and lead to the same result from a different avenue. However, it should be noted that this problematizing effect would not have emerged for Condition 2.

Further (see Table 10), Conditions 1 and 2 improved significantly in “Formulate hypotheses”, whereas Condition 3 did not. The latter findings were validated in the cross-country replication of statistical analyses. Indeed, for each country it was shown that formulating hypotheses improved significantly in both Conditions 1 (Z = -3.45, $p < 0.01$ for UCY; Z = -2.58, $p < 0.05$ for UTE; Z = -2.20, $p < 0.05$ for UT) and 2 (Z = -3.18, $p < 0.01$ for UCY; Z = -2.20, $p < 0.05$ for UTE; Z = -2.75, $p < 0.01$ for UT), but it did not improve significantly in Condition 3.

Table 10. Wilcoxon Signed Ranks Tests for knowledge and skill dimensions across conditions.

	Condition 1	Condition 2	Condition 3
Knowledge dimensions			
“Remember”	-0.71ns	-1.63ns	-1.73ns
“Understand”	-0.69ns	-0.73ns	-0.38ns
“Apply”	-3.00**	-1.81ns	-2.16*
Skill dimensions			
“Identify variables”	-2.15*	-0.05ns	-2.53*
“Formulate hypotheses”	-4.60***	-4.79***	-1.55ns

Note: Z values presented; ns = non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Degree of software scaffolding and the “saturation” effect

We calculated Spearman’s rank correlation coefficients between pre-test scores and change across all knowledge and skill dimensions. In this case, we expected a significant and negative coefficient between pre-test scores and change (post-test scores minus pre-test scores) to indicate that knowledge or skill gains would be substantially less for students with higher prior knowledge or skills across the dimensions we studied, and vice versa, that knowledge or skill gains would be substantially pronounced for students with relatively lower prior knowledge or skills. The nonparametric correlations we have computed for the entire sample are presented in

Table 11. We can observe that all knowledge and skill dimensions revealed such a “saturation” effect across conditions with only one exception. There was no saturation effect for “Formulate hypotheses” in Condition 2. This result might imply that partial scaffolding of the targeted skill would downsize the saturation effect. Namely, students of higher ability would still be able to benefit in the partial scaffolding condition (Condition 2; some words) but not in the fully fledged scaffolding condition (Condition 1; all words) or in the condition with no scaffolding (Condition 3; no words). Based on this finding, we might single out partial scaffolding as more desirable and eligible for software scaffolds, especially in terms of its ability to alleviate or ease the saturation encountered by students with relatively higher prior knowledge or skills. The correlational effect showing no saturation for Condition 2 in formulating hypotheses has been validated by separate analyses run for each country. The general trend in all cases was that, among widespread saturation effects in other knowledge and skill dimensions, there was no significant coefficient for Condition 2 in the targeted skill of formulating hypotheses (Spearman’s rho = -0.29, $p = 0.223$ for UCY; Spearman’s rho = -0.22, $p = 0.573$ for UTE; Spearman’s rho = -0.27, $p = 0.119$ for UT).

Table 11. Spearman's rank correlation coefficients between pre-test scores and change in knowledge and skill dimensions after the intervention.

	Condition 1	Condition 2	Condition 3
Knowledge dimensions			
"Remember"	-0.74***	-0.32*	-0.48***
"Understand"	-0.60***	-0.59***	-0.75***
"Apply"	-0.53***	-0.65***	-0.35**
Skill dimensions			
"Identify variables"	-0.49***	-0.49***	-0.45***
"Formulate hypotheses"	-0.48***	-0.20ns	-0.32**

Note: Figures presented correspond to Spearman's rho calculated between pre-test scores and change across all knowledge and skill dimensions; ns = non-significant; * p < 0.05; ** p < 0.01; *** p < 0.001.

In order to investigate the absence of any saturation effect in Condition 2 for "Formulate hypotheses", we segmented the total sample in two student groups (i.e., student group of low prior skill level vs student group of high prior skill level) using the median value in pre-test scores for this skill dimension (median value for pre-test scores in "Formulate hypotheses" = 0.44) as a threshold. Then, we used pre-test and post-test scores for both student groups across all conditions to conduct additional Wilcoxon Signed Ranks Tests in the targeted skill, separately. The results of these additional analyses are presented in Table 12. The Wilcoxon tests indicated that all conditions in the student group of low prior skill level revealed significant improvement in the targeted skill, whereas only Condition 2 improved significantly in the student group of high prior skill level. These latter findings are in line with what has been already discussed for Spearman's rank correlation coefficients in the former table and provide further support to the absence of saturation effects for the targeted skill ("Formulate hypotheses") in Condition 2.

Table 12. Wilcoxon Signed Ranks Tests across conditions for student groups of low and high prior skill levels in "Formulate hypotheses".

	Condition 1	Condition 2	Condition 3
Student group of low prior skill level (99 students)	-4.40***	-4.49***	-3.26**
Student group of high prior skill level (100 students)	-1.63ns	-2.21*	-0.60ns

Note: Z values presented; ns = non-significant; * p < 0.05; ** p < 0.01; *** p < 0.001.

Second research question

Intercontextual transfer of inquiry skills

We coded student hypotheses formulated in the ILS and another set of hypotheses formulated in a new context after the completion of the ILS (submarine context). We used a rubric to score student hypotheses (Figure 8). Hypotheses were classified in three broad categories: Irrelevant or non-testable statements, testable statements without interaction effect between object and fluid, and testable statements with interaction between object and fluid. Although conditions did not differ in the hypotheses formulated in the ILS (

Table 13), a first indication of intercontextual transfer was a significant Chi-square value between hypotheses formulated in the ILS and hypotheses formulated in the novel context (submarine context; Table 14), which implied that students tended to carry along their ability to formulate hypotheses in the context encountered after they had exited the ILS. We have to underline that Condition 3 managed to also present clear indications of intercontextual transfer together with Conditions 1 and 2. In that regard, we have to note the significant effects for Condition 3 in Table 10 concerning “Apply” and “Identify variables”, which were both enhanced after the intervention and which might have contributed to intercontextual transfer.

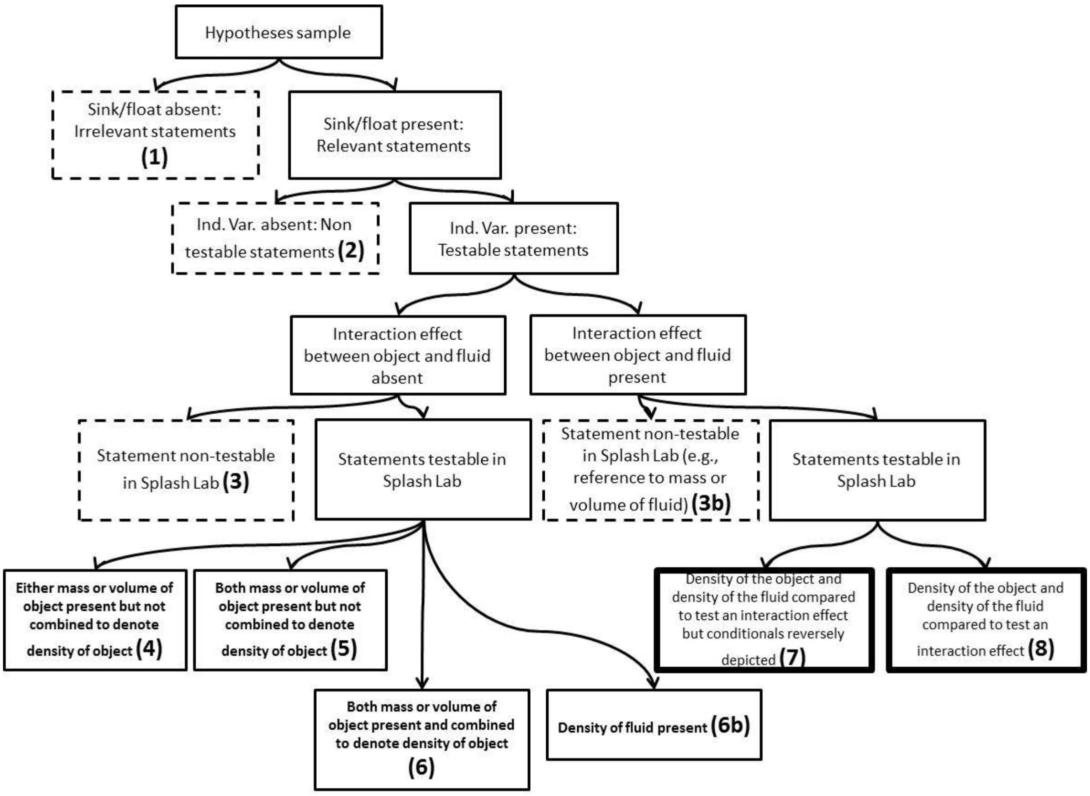


Figure 14. Rubric employed to score student hypotheses in the ILS and in the new context (submarine context). Rectangles with dashed lines depict irrelevant or non-testable statements formulated by students (1; 2; 3; 3b). Rectangles with continuous lines stand for testable statements without interaction effect between object and fluid (4; 5; 6; 6b), while rectangles with bold lines correspond to testable statements with interaction between object and fluid (7; 8).

Table 13. Hypotheses scores across conditions in the Inquiry Learning Space.

	Condition 1 (% of students)	Condition 2 % of students)	Condition 3 (% of students)
Irrelevant or non-testable statements	31 (44.9)	28 (44.4)	25 (37.3)
Testable statements without interaction effect between object and fluid	18 (26.1)	24 (38.1)	26 (38.8)
Testable statements with interaction between object and fluid	20 (29.0)	11 (17.5)	16 (23.9)

Note: Number presented correspond to number of students, while percentages for each condition are given in parentheses; Likelihood ratio Chi-Square = 4.60; $p > 0.05$.

Table 14. Crosstabulation of hypotheses scores across learning contexts.

	Inquiry Learning Space (% of students)	Submarine context (% of students)
Irrelevant or non-testable statements	79 (47.6)	85 (52.2)
Testable statements without interaction effect between object and fluid	49 (29.5)	66 (39.8)
Testable statements with interaction between object and fluid	38 (22.9)	15 (9.0)

Note: Number presented correspond to number of students, while percentages for each learning context are given in parentheses; Likelihood ratio Chi-square between contexts = 12.05; $p < 0.05$, Phi = 0.28; $p < 0.05$.

Further, we computed a new variable depicting progression in formulating hypotheses in student transition from the ILS to the novel context. This was a binary variable distinguishing students who progressed from those who did not. “Progression” would denote a transition from irrelevant or non-testable statements (non-testable within the Splash-Lab, which students have had the opportunity to familiarize with), formulated by students as hypotheses in the ILS, to testable statements in the new context (submarine context). In an analogous manner, “progression” could also denote a transition from testable hypotheses without interaction effect between object and fluid to testable hypotheses with an interaction effect in the new context. About one out of five students progressed in this transition.

We performed a binary logistic regression using this variable as a dependent one. To prepare independent variables for this regression, we computed “improvement” in the ILS across all knowledge and skill dimensions as binary variables. For instance, “improvement” in a dimension (1) would separate students who had developed this knowledge or skill dimension (post-test score higher than the pre-test score) from those who did not (0). We employed a stepwise forward method and found that “Apply” was the only independent variable which contributed significantly in predicting student progression (forward conditional method; Change in -2 Log Likelihood = 6.97; $p < 0.01$, overall percentage of students correctly predicted = 78.9%). Namely, those students who had improved in a metacognitive dimension (“Apply”) would be more probable to also have progressed in formulating hypotheses from the learning context to the new context they had encountered. Replication of this analysis in the two countries, which had followed the design with new learning context (UT and UCY) revealed analogous trends. Specifically, UT data closely resembled the overall trend, depicting “Apply”, once again, as the unique predictor of student progression in formulating hypotheses (forward conditional method; Change in -2 Log Likelihood = 5.55; $p < 0.05$, overall percentage of students correctly predicted = 79.8%). In UCY data, “Apply” failed to be significant but it presented the lowest significance level among predictors (Score = 1.72, $p = 0.190$). We run the analysis using a different method (enter) and in this case “Apply” was once more the predictor with the highest relative weight among independent variables (Wald statistic = 2.80, $p = 0.094$). In both cases, “Apply” had been quite close to being significant, and in any case, it had been much closer to being significant than any other independent variable.

1.4.4 Discussion

Additional data analyses on the Hypothesis Scratchpad revealed that some degree of software scaffolding is needed to support the formulation of hypotheses. However, partial scaffolding might be more preferable than full scaffolding in the targeted skill, especially in terms of addressing saturation effects (see also Judson, 2012 for a discussion of “ceiling” effects), and this might indicate that partial scaffolding might strike a better balance between structuring tasks and problematizing student inquiry, when targeting hypotheses formulation. This finding was obtained in all locations, which adds to its consistency in terms of cultural heterogeneity and convergent validity.

Another major finding was that intercontextual transfer of formulating hypotheses was mediated by metacognitive processes (i.e., “Apply”). This is in line with previous research that underlined the linkages of metacognition to transfer of learning in new contexts (Kapa, 2007; Kuhn & Dean, 2004). Overall, the Hypothesis Scratchpad might prove quite valuable for promoting scientific inquiry skills not only in the learning environment under reference, but also in upcoming learning contexts.

1.4.5 References

De Backer, L., Van Keer, H., & Valcke, M. (2016). Eliciting reciprocal peer-tutoring groups’ metacognitive regulation through structuring and problematizing scaffolds. *The Journal of Experimental Education,* 84, 804–828, 2016. doi: 10.1080/00220973.2015.1134419

Judson. E. (2012). Learning about bones at a science museum: examining the alternate hypotheses of ceiling effect and prior knowledge. *Instructional Science*, 40, 957-973. doi 10.1007/s11251-011-9201-6

Kapa, E. (2007). Transfer from structured to open-ended problem solving in a computerized metacognitive environment. *Learning and Instruction*, 17, 688–707. http://dx.doi.org/10.1016/j.learninstruc.2007.09.019

Kuhn, D., & Dean, D. (2004). A bridge between cognitive psychology and educational practice. *Theory into Practice*, 43, 268–273. http://dx.doi.org/10.1207/s15430421tip4304_4

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2010). The effects of scaffolding metacognitive activities in small groups. *Computers in Human Behavior*, 26, 1727–1738. http://dx.doi.org/10.1016/j.chb.2010.06.022

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2011). Metacognitive scaffolding in an innovative learning arrangement. *Instructional Science* 39, 785-803. doi 10.1007/s11251-010-9154-1

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences*, 13, 273-304. doi:10.1207/s15327809jls1303_2

1.5 Common Study 2: The effect of going through multiple Learning Activity Spaces on student knowledge, motivation and attitudes toward science.

1.5.1 Abstract

The present study aimed at assessing changes in student knowledge, motivation, and attitudes toward science after a prolonged learning activity sequence that evolved through multiple Learning Activity Spaces. A major finding that was validated across all countries that participated in the current study was the improvement in organizing and arranging scientific knowledge mentally (i.e., “Understand”). However, our results did not include any consistent pattern of improvement in student motivation or attitudes toward science across locations. The present study provided insightful results in terms of knowledge effects on student motivation. Overall, our results seem to be in line with previous research, which indicated a reinforcing effect of student knowledge on student motivation. Indeed, thinking critically and creatively was found to promote career motivation. However, we need to highlight the fact that these effects emerged only in the case of the most demanding and metacognitive knowledge dimension (i.e., thinking critically and creatively), which might imply that they are not to be expected easily and unconditionally across learning contexts.

1.5.2 Introduction

Research on student motivation and attitudes towards science showed a positive interrelation between scientific knowledge, on the one hand, and student motivation and attitudes, on the other (e.g., Acar Sesen & Tarhan 2013; Beerenwinkel & von Arx, 2016; Klop et al., 2010). Indeed, these effects of scientific knowledge might even proceed to include career motivation (Park et al., 2009). However, these effects might not be readily expected after a few learning activities. Instead, they might demand a considerable route through trajectories in scientific inquiry.

The present study aimed at assessing the effect on student knowledge motivation, and attitudes toward science after a prolonged learning activity sequence that evolved through multiple Learning Activity Spaces (ILSs). We had two main research questions. First, to investigate significant changes in dimensions of knowledge, motivation, and attitudes toward science. Second, to examine interrelations among knowledge dimensions, on the one hand, and motivation or attitudes toward science, on the other. To provide convergent validity to our results, we replicated the study in four different locations (see Methods section; Participants).

1.5.3 Methods

Common Study 2 involved the implementation of three subsequent ILSs in a row, which focused on electrical circuits. More specifically, the first ILS introduced types of circuits, the second built on electric current measurements, while the third ILS addressed the Ohm’s Law. The study was conducted in four countries, namely, Cyprus, the Netherlands, the UK, and Estonia. Before and after the intervention, students completed three questionnaires on knowledge, motivation and attitudes, respectively.

1.5.4 Participants

After deletion of various students who provided incomplete data, the final sample of Common Study 2 included 121 secondary students (15-17 years old; 16 in Cyprus, 21 in the Netherlands, 39 in the UK, and 45 in Estonia).

1.5.5 Materials

Learning enviroment

Learning activities were undertaken in three online ILSs, which were developed within the inquiry cycle design framework (Pedaste et al., 2015), by means of the Graasp authoring tool (see de Jong, Sotiriou & Gillet, 2014; Rodriguez-Triana, Holzer, Vozniuk, & Gillet, 2015). The content of each ILS referred to the electrical circuits and included the Electrical Circuit Lab (Figure 15), which is available on the Go-Lab platform (http://www.golabz.eu/lab/electrical-circuit-lab). In addition, each ILS was divided in five inquiry phases, namely, the *Orientation*, the *Conceptualization (Hypothesis sub-phase)*, the *Investigation (Experimentation sub-phase)*, the *Conclusion* and the *Discussion (Reflection sub-phase)* phase. Moreover, each ILS included software scaffolds to guide students when undertaking learning tasks.

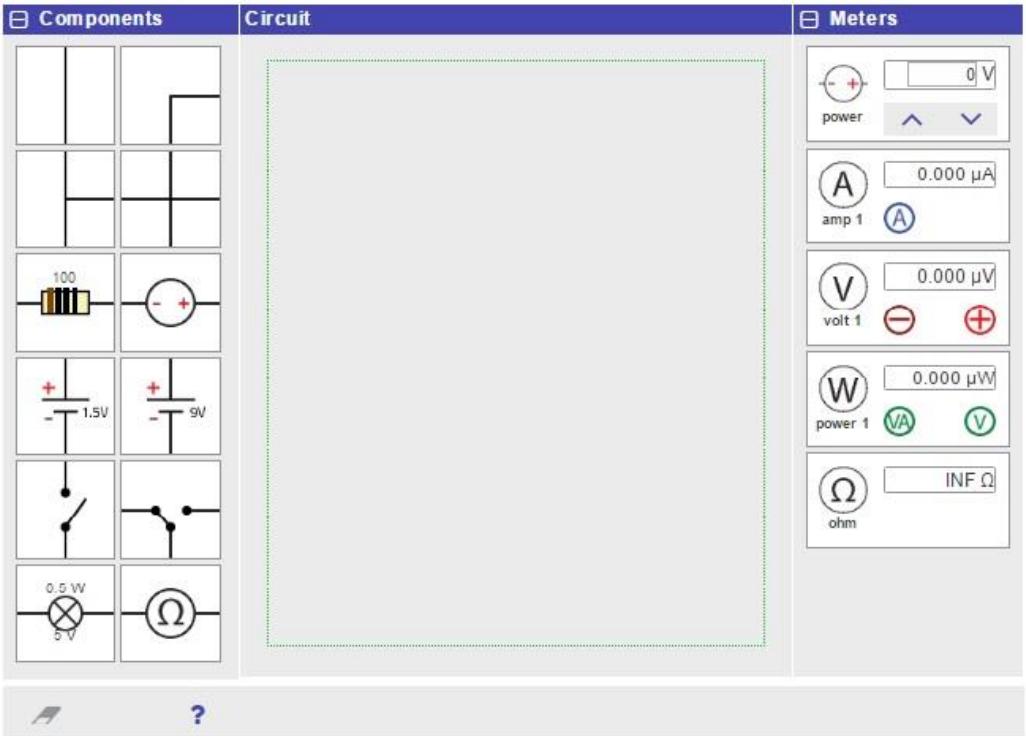


Figure 15. The Electrical Circuit Lab.

First ILS: Types of electrical circuits

The overall goal of the first ILS was to familiarize students with the types of electrical circuits, specifically the simple electrical circuit and the circuits connected in series and in parallel. In the *Orientation* phase, students watched a video about the simple electrical circuit, and then, they created a circuit using real equipment (a battery, a wire, and a bulb). Afterwards, they became familiar with the two types of connection, in series and in parallel, and they answered a quiz. In the *Hypothesis* phase, students were asked to make predictions about the brightness of the bulbs in series and in parallel circuits, as compared against the brightness of a single bulb in a simple electrical circuit. Then, based on their predictions, they formulated hypotheses on how the brightness of the bulbs would be impacted, when the number of bulbs increased in series and in parallel. The learning activity of formulating hypotheses was supported by the Hypothesis Scratchpad (Figure 16), where students were provided with predefined conditionals and concepts that they could drag and drop in the hypothesis box to create a hypothesis in the form of an "if…then" statement. Students could also type their own words or phrases and place them in the hypothesis box. Additionally, students could adjust their confidence level for each hypothesis they had formulated, by changing the color of the "horseshoe" placed next to the hypothesis box. If the "horseshoe" was blue, overall, that would mean that a student was absolutely confident that his/her hypothesis was correct.

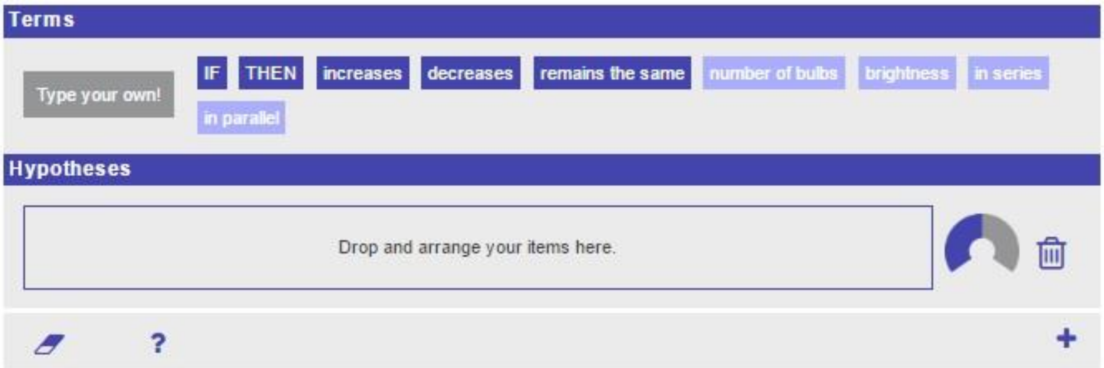


Figure 16. The Hypothesis Scratchpad.

After hypotheses had been formulated, students continued to the *Conceptualization* phase (*Experimentation sub-phase*). First, they became familiar with the Electrical Circuit Lab by watching a demonstration video, and then, they designed and executed their experiments to confirm or reject their hypotheses. In order to plan a valid experimental design, they used the Experiment Design Tool (Figure 17). This software scaffold splits the learning task of the experimental design in three sub-tasks. First, students had to decide which variable to vary (independent variable), which variables to keep constant (control variables) and which variable to measure/observe (dependent variable). To complete this task, students dragged the variables from the left side of the tool and dropped them to the proper column. The second sub-task involved the addition of all experimental trials that had to be undertaken, while the third sub-task concerned the determination of values of variables in each experimental trial.

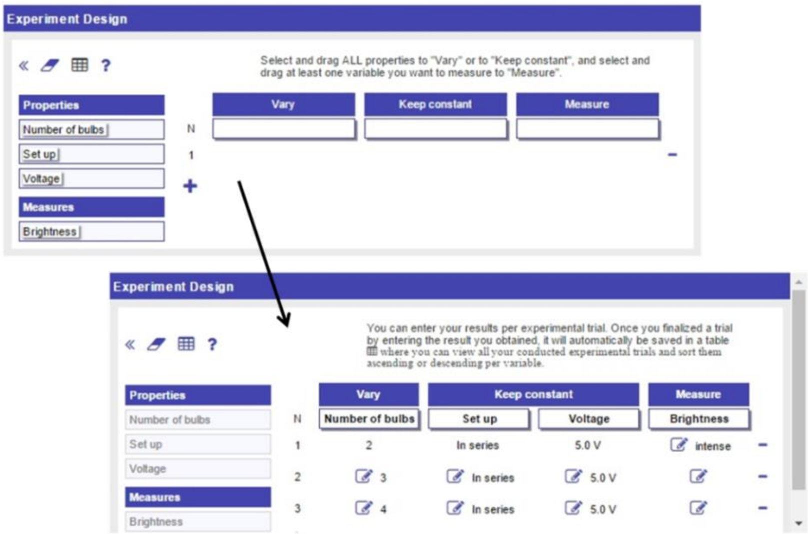


Figure 17. The Experiment Design Tool.

During experimentation, students were prompted to keep notes about ideas, thoughts and observations by means of the Observation Tool (Figure 18).

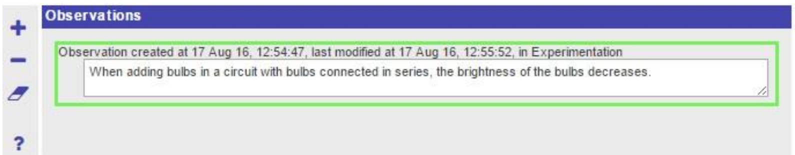


Figure 18. The Observation Tool.

In the *Conclusion* phase, students used the Conclusion Tool (Figure 19) to retrieve their hypotheses and observations in order to argue how their confidence for each hypothesis had changed after their experimentation.

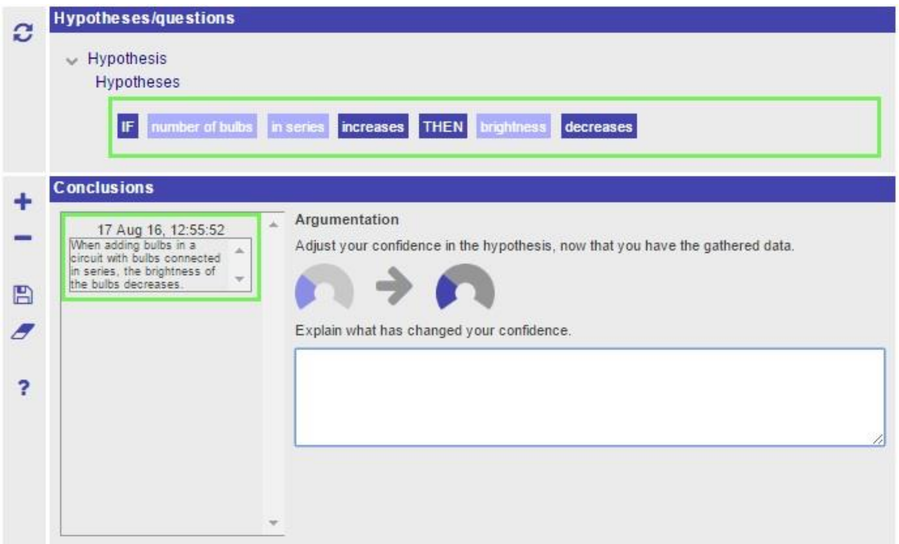


Figure 19. The Conclusion Tool.

In the last phase (*Discussion* phase; *Reflection* sub-phase) students reflected on time spent in each phase by means of the Reflection Tool (Figure 20).

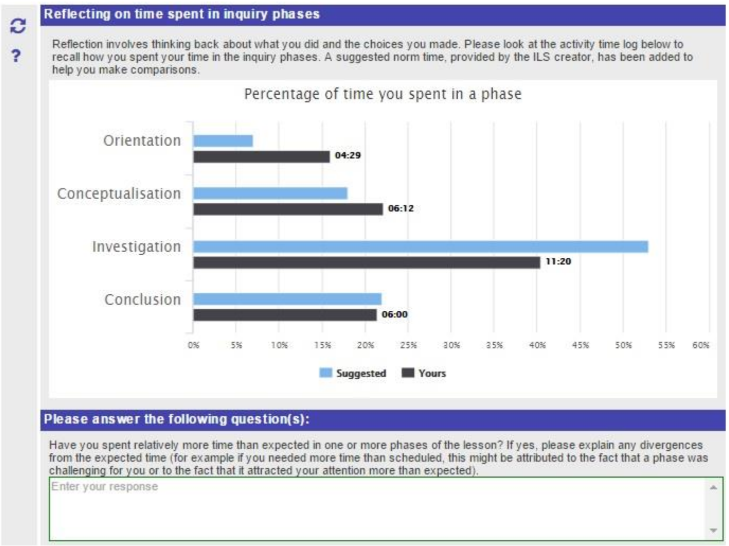


Figure 20. The Reflection Tool.

Second and third ILSs: Electric current measurements and Ohm's law

The learning activity sequences of the second and third ILSs was similar with those of the first ILS. The only difference was the addition of the *Data Interpretation* sub-phase, after experimentation. In this sub-phase, students plotted graphs using data collected in their experimentation, in order to interpret their findings. To do so, they used the Data Viewer (Figure 21). In that tool, students had access to all variables recorded in the Experiment Design Tool. For that purpose, all variables were loaded to the left side of the tool's interface and students had to select two of them, anytime they wished to construct a graph.

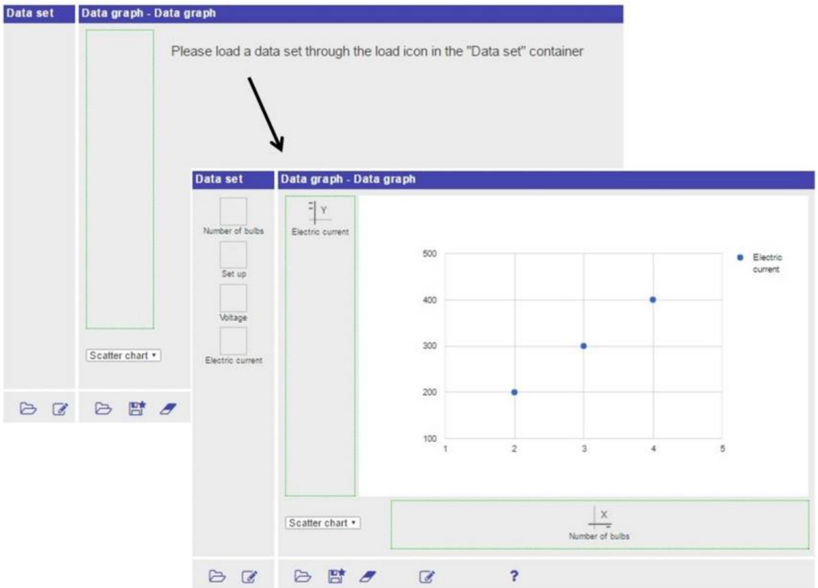


Figure 21. The Data Viewer.

1.5.6 Assessment

Data collection involved one questionnaire on knowledge, another one on motivation and a third one on attitudes.

For the knowledge test, we used a revised taxonomy of the levels of the cognitive domain of knowledge (see de Jong, 2014; Zervas, 2013). Factors incorporated in the instrument were "Remember" (2 items), "Understand" (2 items), "Apply" (2 items) and "Think critically and creatively" (1 item). Knowledge items focused on the simple electrical circuit, the differences of the circuits connected in series and in parallel, especially in terms of the brightness of the bulbs and the electric current, and the Ohm's law.

The motivation questionnaire included four out of the five factors of the questionnaire developed by Glynn (2011), namely: *Intrinsic motivation* (5 items), *Self-efficacy* (5 items), *Self-determination* (6 items) and *Career motivation* (5 items).

The questionnaire on attitudes included six factors proposed by Kind, Jones, and Barmby (2007), namely: *Learning science in school* (6 items), *Self-concept in science* (7 items), *Practical work in science* (8 items), *Science outside of school* (6 items), *Future participation in science* (4 items) and *Importance of science* (3 items). All items were measured along a five-point Likert scale. Scores across each factor were rescaled to range between 0 and 1.

1.5.7 Procedure

All implementations were carried out by science teachers in each country and they involved three phases. In the first phase, students completed pre-tests, in the second phase they undertook the learning activities in the three ILSs, and in the third phase students completed post-tests.

1.5.8 Results

Pre- and post-test averages of knowledge, motivation, and attitude factors

Pre- and post-test averages of knowledge, motivation, and attitude factors across countries are presented in Table 15. A significant knowledge improvement, which was common across all countries, was the enhancement of the "Understand" factor among cognitive processes. Various other effects on knowledge could have proven significant, but they were not homogeneous among countries and they were not recorded at the same level of significance. Effects on motivation factors were scarce and contradictory among locations. For instance, career motivation was more pronounced after the implementation for students in Estonia but it was less pronounced in the Netherlands. An analogous scattered image appeared for attitude dimensions, too. In this case, however, all changes after the implementation concerned a decrease in scores.

Table 15. Pre- and post-test averages of knowledge, motivation, and attitude factors across countries.

	Knowledge factors[1]				Motivation factors[2]				Attitude factors[3]					
	Rem	Und	App	Cri	Int	Eff	Det	Car	Lea	Sel	Pra	Out	Par	Imp
UCY_pre	0.41	0.40	0.53	0.11	0.84	0.72	0.72	0.84	0.85	0.68	0.78	0.83	0.83	0.85
UCY_post	0.47	0.80	0.81	0.25	0.86	0.71	0.69	0.78	0.81	0.66	0.80	0.64	0.68	0.73
Z[4]	-1.03	-2.82**	-2.52*	-1.86	-1.24	-0.96	-1.03	-1.86	-0.91	-1.05	-0.80	-3.06**	-1.27	-1.81
UT_pre	0.50	0.21	0.01	0.17	0.63	0.5	0.73	0.71	0.58	0.66	0.77	0.55	0.58	0.83
UT_post	0.57	0.51	0.01	0.20	0.58	0.65	0.72	0.67	0.64	0.54	0.76	0.51	0.53	0.79
Z[4]	-1.30	-3.15**	-0.45	-0.45	-2.40*	-0.17	-1.10	2.39*	-1.79	-3.31**	-1.39	-1.52	-1.79	-2.20*
ULEIC_pre	0.32	0.38	0.02	0.05	0.65	0.64	0.72	0.68	0.57	0.56	0.69	0.57	0.57	0.74
ULEIC_post	0.33	0.63	0.04	0.04	0.66	0.64	0.70	0.68	0.57	0.55	0.66	0.58	0.57	0.74
Z[4]	-0.87	-4.26***	-1.56	-0.00	-1.08	-0.01	-0.61	-0.06	-0.54	-0.58	-1.67	-0.56	-0.29	-0.22
UTE_pre	0.29	0.49	0.31	0.09	0.73	0.72	0.65	0.59	0.63	0.72	0.70	0.67	0.53	0.85
UTE_post	0.39	0.68	0.41	0.09	0.72	0.74	0.64	0.66	0.65	0.72	0.66	0.69	0.54	0.82
Z[4]	-3.77***	-2.73**	-2.11*	-0.04	-1.28	-1.14	-0.60	-2.41*	-0.61	-0.37	-2.30*	-0.21	-0.90	-1.39

1: “Rem” = Remember; “Und” = Understand; “App” = Apply; “Cri” = Think critically and creatively.
2: “Int” = Intrinsic motivation; “Eff” = Self-efficacy; “Det” = Self-determination; “Car” = Career motivation.
3: “Lea” = Learning science in school; “Sel” = Self-concept in science; “Pra” = Practical work in science; “Out” = Science outside of schools; “Par” = Future participation in science; “Imp” = Importance of science.
4: *Z* of Wilcoxon Signed Ranks Tests; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Correlations among change in knowledge, motivation, and attitude factors

Pre-test scores were subtracted from post-test scores to derive the difference across factors after the educational intervention. Changes for all factors were correlated for the entire sample. This revealed three significant correlations among change in knowledge factors and motivation dimensions. Specifically, improvement in thinking critically and creatively (knowledge factor) was positively correlated to intrinsic motivation (Spearman's rho = 0.36; $p < 0.001$), self-determination (Spearman's rho = 0.20; $p < 0.05$), and career motivation (Spearman's rho = 0.22; $p < 0.05$) (motivation factors).

1.5.9 Discussion

A major finding that was validated across all countries in the current study was the improvement in organizing and arranging scientific knowledge mentally (i.e., "Understand"; see de Jong, 2014; Zervas, 2013). However, our results did not include any consistent pattern of improvement in student motivation or attitudes toward science across locations. Indeed, there was an indication that some attitude scores faded out in some locations. It could be that some individual routes all along three subsequent ILSs might have triggered feelings of fatigue and displeasure, which have been reported to indicate counter-motives for being engaged with science (Masnick et al., 2010). Future research might further explore these effects in both individual and collaborative learning settings.

The present study provided insightful results in terms of knowledge effects on student motivation. Overall, our results seem to be in line with previous research, which indicated a reinforcing effect of student knowledge on student motivation (Beerenwinkel & von Arx, 2016). One of the knowledge dimensions (i.e., thinking critically and creatively) was linked to intrinsic motivation, namely, a drive initiated by the interest and joy students might associate with science (Ryan & Deci, 2000). Indeed, thinking critically and creatively was also found to promote career motivation, which has been highlighted as a possible influence by previous research (Park et al., 2009). However, we need to highlight the fact that these effects emerged only in the case of the most demanding and metacognitive knowledge dimension (i.e., thinking critically and creatively), which might imply that they are not to be expected easily and unconditionally across learning contexts.

1.5.10 References

Acar Sesen, B., & Tarhan, L. (2013). Inquiry-Based Laboratory Activities in Electrochemistry: High School Students' Achievements and Attitudes. *Research in Science Education*, 43, 413-435. DOI 10.1007/s11165-011-9275-9

Beerenwinkel, A., & von Arx, M. (2016). Constructivism in practice: An exploratory study of teaching patterns and student motivation in physics classrooms in Finland, Germany and Switzerland. *Research in Science Education*, DOI 10.1007/s11165-015-9497-3

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, 48, 1159-1176. DOI: 10.1002/tea.20442

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education*, 29, 871-893. http://dx.doi.org/10.1080/09500690600909091

Klop , T., Severiens, S. E., Knippels , M.-C. P. J., van Mil, M. H. W., & Ten Dam, G. T. M. (2010). Effects of a science education module on attitudes towards modern biotechnology of secondary school students. *International Journal of Science Education*, 32, 1127-1150. doi: 10.1080/09500690902943665

Masnick , A. M., S. Stavros Valenti, S., Cox, B. D., & Osman, C. J. (2010). A multidimensional scaling analysis of students' attitudes about science careers. *International Journal of Science Education*, 32, 653-667. doi: 10.1080/09500690902759053

Park H., Khan, S., & Petrina, S. (2009). ICT in science education: A quasi-experimental study of achievement, attitudes toward science, and career aspirations of Korean middle school students. *International Journal of Science Education*, 31, 993-1012. http://dx.doi.org/10.1080/09500690701787891

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, 25, 54–67. doi:10.1006/ceps.1999.1020

1.6 Study 6: Examining the Effect of a Hypothesis Formulation Tool and an Experiment Design Tool on Students' Learning when Using Web-based Science Virtual Labs in an Inquiry Context.

Tasos Hovardas, Nikoletta Xenofontos, & Zacharias C. Zacharia
Research in Science and Technology Education Group, Department of Education, University of Cyprus

[This paper has been submitted as a book chapter to be included in I. Levin, & D. Tsybulsky (Eds.), Digital tools and solutions for inquiry based STEM learning. IGI Global.]

1.6.1 Abstract

The challenge of configuring the best balance between guidance and openness in inquiry learning translates, in computer-supported learning environments, into an analogous delicate tension between structuring student work, on the one hand, and "problematizing" student inquiry, on the other. The present study employed two different tools, which were developed within the Go-Lab project (http://www.go-lab-project.eu/). These tools were used by primary school students to carry out successive learning tasks during experimentation. The first tool assisted learners in formulating hypotheses (Hypothesis Scratchpad), while the second tool guided students in designing experiments (Experiment Design Tool). Both tools were designed to take into account the trade-offs between structuring and problematizing student inquiry. Our core objective was to investigate the effect of each tool separately, as well as the combined effect of the tools in supporting student work. Participants were 41 fifth graders from two classes of a public primary school in Larnaca, Cyprus. They were randomly assigned to four conditions: Condition 1 involved use of both tools, Condition 2 included the Hypothesis Scratchpad only, Condition 3 included the EDT only, and Condition 4 had no tools provided. Conditions including one of the two tools outperformed the condition with no tools in the corresponding skill scaffolded by the tool. The cumulative effect of both tools seems to have been greater than the effect of each tool separately in novel inquiry contexts. Our results imply that transfer can be assessed with two different scales. The first addresses the transition between different contexts (inter-contextual transfer), while the second is anchored within a single learning activity sequence and refers to gains transferred from a learning task to an upcoming learning activity (inter-task transfer).

Keywords

Combined effect of software scaffolds; computer-supported learning environments; problematizing student inquiry; software scaffolds; structuring student inquiry

1.6.2 Introduction

The optimal degree of guidance for supporting student inquiry in science education has long been debated (Arnold, Kremer, & Mayer, 2014). Although previous research has highlighted the possibility that guided inquiry could be beneficial for learners, for instance, in improving science process skills (e.g., Kirschner, Sweller, & Clark, 2006; Koksal & Berberoglou, 2014), there is always the need to engage students as active learners in inquiry-based science instruction, capable of taking over responsibility for a range of tasks (Minner, Jurist Levy, & Century, 2010). This unresolved controversy over emphasis on guidance, at the one extreme, and openness, at the other, has been also reflected in the design of computer-supported learning environments. In this case, guidance is taken over by software scaffolds, which aim to structure student tasks in order to decrease complexity and offload certain aspects of a variety of tasks (de Jong, 2006; Pea, 2004; Reiser, 2004; Reiser et al., 2001; Simons & Klein, 2007; van Joolingen, 1999). If technology can narrow down the multiplicity of potential routes students might follow, then student effort can be devoted to following these more tractable trajectories. However, a rigidly structured learning activity sequence would not readily allow students to assume any responsibility for their inquiry (e.g., Chang, Chen, Lin, & Sung, 2008).

The challenge of configuring the best balance between guidance and openness in inquiry learning translates, in computer-supported learning environments, into an analogous delicate tension between structuring student work, on the one hand, and “problematizing” student inquiry, on the other (Reiser, 2004). Eliminating task complexity, overall, might endanger students' active engagement and lock them into unproductive pathways. After any learning gain has been accomplished, the tasks that follow should test out student competence at a higher level, beyond their current expertise (Kalyuga, 2007). In contrast to structuring, which removes complexity, problematizing student inquiry introduces complexity (Reiser, 2004), at least up to a point, so that the difficulty students are confronted with always surpasses the knowledge and skills they have already acquired. By adding such challenge, learning and instruction can maintain their productive character, and learner focus then needs to be re-directed towards parts of the task that otherwise might not be addressed (Reiser, 2004). Despite the unsettled theoretical and methodological interplay between structuring and problematizing student work, the question of how to problematize inquiry has not yet received the attention it deserves in the relevant literature (Reiser, 2004).

The contrast between structuring and problematizing student inquiry is pronounced in procedures that involve a series of interrelated tasks to be completed (Reiser, 2004). Such a situation is encountered in scientific experimentation, which involves identifying variables, formulating hypotheses, designing and executing experiments, gathering, analysing, and interpreting data (e.g., Germann, Aram, & Burke, 1996; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Kremer, Specht, Urhahne, & Mayer, 2014; van Joolingen & Zacharia, 2009). Students face quite a few obstacles in designing and executing valid experiments (de Jong, 2006; Reiser, 2004; Zacharia, Manoli, Xenofontos, de Jong, Pedaste, van Riesen, et al., 2015); such obstacles include, among others, classifying variables as dependent, independent and controlled, and planning experimental trials (e.g., Arnold et al., 2014; Chinn & Malhotra, 2002; De Boer, Quellmalz, Davenport, Timms, Herrmann-Abell, Buckley, Jordan, et al., 2014; Lin & Lehman, 1999; Roberts & Gott, 2003; van Joolingen & de Jong, 1991). Due to the modular and difficult nature of experimentation, obstacles have been identified even among older students (Arnold et al., 2014; Furtak, 2006; Germann et al., 1996; Kirschner et al., 2006).

Therefore, it should not be surprising that experimentation is the part of the inquiry cycle that has been most often supported by software scaffolds (Zacharia et al., 2015).

Research on the impact of software scaffolds on experimentation has delivered mixed results (e.g., Zacharia et al., 2015). More to the point, previous studies have been confined to examining separate tools and scaffolds, whereas experimentation involves a set of stages that need to be effectively executed. The present study employed two different tools, which were developed within the Go-Lab project (http://www.go-lab-project.eu/), and which were used by primary school students to carry out successive learning tasks during experimentation. The first tool assisted learners in formulating hypotheses ("Hypothesis Scratchpad"; http://www.golabz.eu/app/hypothesis-tool), while the second tool guided students in designing experiments ("Experiment Design Tool"; http://www.golabz.eu/apps/experiment-design-tool). Both tools were designed to take into account the trade-offs between structuring and problematizing student inquiry, as previously discussed. Our core objective was to investigate the effect of each tool separately as well as the combined effect of the tools in supporting student work. Our first research question, in this regard, was whether each tool separately supported student inquiry. Our second research question was whether using both tools yielded higher learning gains than using each tool separately. Another objective was to examine transferability of learning gains, using two different scales. Along these lines, our third research question involved transferability of learning gains to a novel learning context that students had not yet encountered. In this case, we examined whether students were able to apply the skills they had acquired in a learning environment, when confronted with a novel inquiry context. The fourth research question concerned whether a valid hypothesis was correlated with a valid experimental design and, further, whether a valid experimental design was accompanied by effective execution of the experiment in a virtual lab. Our fifth and final research question concerned a determination of the relative weight of each variable studied (i.e., variables referring to software scaffolds and to learning products during the learning activity sequence) across conditions (i.e., participants given each tool separately; those given both tools; and those given no tools).

1.6.3 Methods

Learning environment

We used the Graasp authoring tool to create an online Inquiry Learning Environment (ILS) (for details on ILSs, see: de Jong, Sotiriou, & Gillet, 2014; Govaerts, Cao, Vozniuk, Holzer, Zutin, Ruiz, et al. 2013; Rodríguez-Triana, Holzer, Vozniuk, & Gillet, 2015), following the inquiry cycle design framework (Pedaste et al., 2015). An ILS is an online computer-supported learning environment, which is designed as a template within the Go-Lab project. The ILS is structured around a virtual laboratory (http://www.golabz.eu/labs) and provides software scaffolds for students undertaking learning tasks (http://www.golabz.eu/apps). The content of the ILS referred to electrical circuits and included the Electrical Circuit Lab (Figure 22), which is available on the Go-Lab platform (http://www.golabz.eu/lab/electrical-circuit-lab). The focus of the study was on the effect of two tools, namely, the Hypothesis Scratchpad (HS) and the Experiment Design Tool (EDT), both when these tools are used separately, and when they are present together in the learning environment. In the latter case, we wished to examine the combined effect of both tools. Therefore, we developed four different versions of the same ILS. The first version included both the HS and the EDT, the second and third versions included only the HS or the EDT, respectively, while the fourth version included neither the HS nor the EDT. Whenever a software scaffold was absent, it was replaced by an Input Box (http://www.golabz.eu/apps/input-box), which is a simple note-taking application and does not provide the specific scaffolding functionalities of either the HS or the EDT.

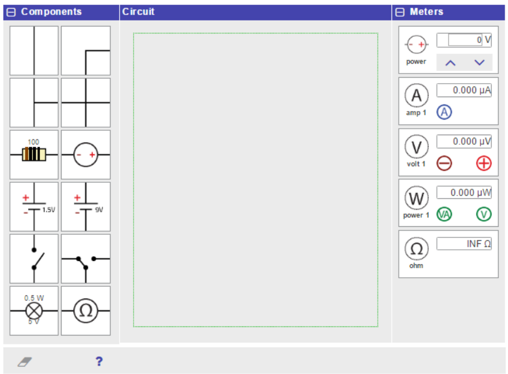


Figure 22. The Electrical Circuit Lab (http://www.golabz.eu/lab/electrical-circuit-lab).

The Hypothesis Scratchpad

Terms needed for formulating a hypothesis were given in the upper part of the HS (Figure 23). Students could drag and drop predefined conditionals and concepts in the space provided by the tool to create a hypothesis in the form of an "if…then" statement. Students could also create their own words or phrases in order to use them in their hypotheses by typing them in the gray box in the tool. Students who used the Input Box instead of the HS formulated their hypotheses without receiving any support in the form of keywords.

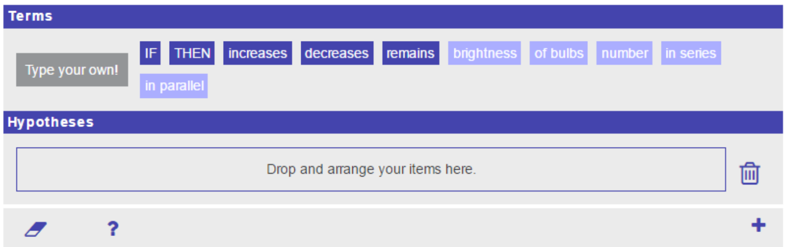


Figure 23. The Hypothesis Scratchpad (http://www.golabz.eu/app/hypothesis-tool).

The Experiment Design Tool

The EDT (Figure 24) included, first, a classification task, where students had to distinguish which variable to vary (independent variable), which variables to keep constant (control variables), and which variable to measure (dependent variable). To do so, students dragged pre-set variables from the left side of the tool´s interface and dropped them in the proper column. A second task involved the arrangement of experimental trials to be undertaken. Students had to specify the values of each variable in each experimental trial they added to their experimental design. Students who used the Input Box instead of the EDT completed their experimental designs without receiving any support in terms of classifying variables or setting values for their experimental trials.

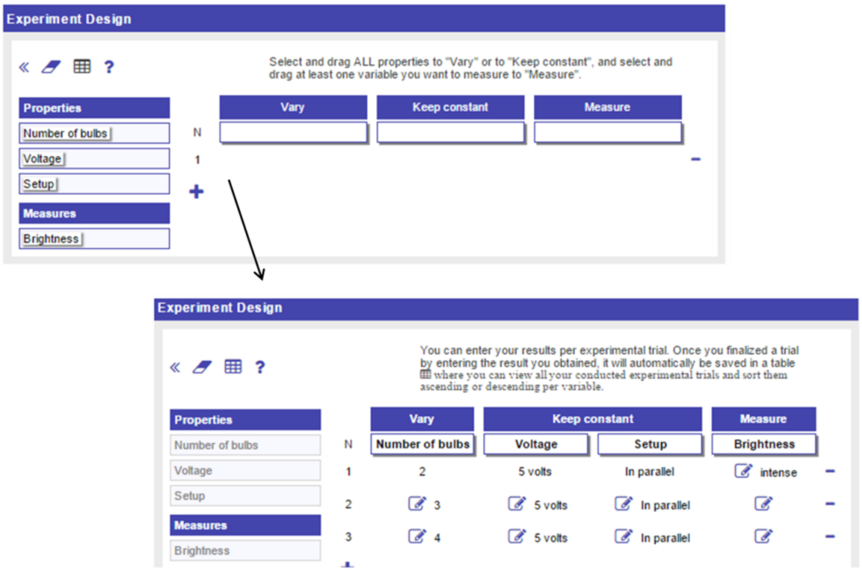


Figure 24. The Experiment Design Tool (http://www.golabz.eu/apps/experiment-design-tool).

1.6.4 Participants

Participants were 41 fifth graders (10-11 years old) from two classes of a public primary school in Larnaca, Cyprus. They were randomly assigned to four conditions: Condition 1 involved both tools (HS+EDT; 11 students; 6 boys, 5 girls), Condition 2 included the HS only (12 students; 6 boys, 6 girls), Condition 3 included the EDT only (9 students; 4 boys, 5 girls), and Condition 4 involved neither the HS nor the EDT (9 students; 5 boys, 4 girls). Students in all conditions were taught about the simple electrical circuit at the beginning of the school year, while the current study was conducted at the end of the same school year. Two pre-tests showed that conditions differed in neither the skills of formulating hypotheses and designing experiments (two scales from the TIPSII inquiry skills test, focused on formulating hypotheses and designing experiments, respectively; see Burns, Okey, & Wise, 1985) nor in their prior knowledge (knowledge dimensions examined were “remember”, “understand” and “apply”; for a detailed description of pre-tests see the sub-section on Data collection and analyses). All students had basic computer and processing skills.

1.6.5 Learning activity sequence

The learning activity sequence started with an Orientation phase, where students were first reminded of the simple electrical circuit and then were introduced to circuits connected in series and in parallel, through videos, diagrams and text. This preliminary set of learning activities ended with a problem presented to students, which referred to how light fixtures in a house are connected. After this introductory phase, students proceeded to the Conceptualization phase, where they had to predict how the brightness of bulbs connected in series and in parallel would differ from the brightness of bulbs in a simple electrical circuit. Afterwards, students formulated hypotheses on how the brightness of bulbs would be impacted when adding more bulbs to circuits in series and in parallel. The next phase involved designing an experiment and executing the experiment in the Electrical Circuit Lab (Investigation phase). When the experimentation procedure had been completed, students responded to several questions in order to interpret their results. The last activity in the Investigation phase was an examination of what would happen when a bulb in a circuit, connected either in series or in parallel, burned out but was not removed from the circuit. In the Conclusion phase, students were asked to provide an answer for the initial problem stated in the ILS, which was about how the light fixtures in a house are connected. Students were prompted to provide enough evidence to justify their answer. The inquiry cycle ended with the Discussion phase, in which students responded to several reflection questions. They were asked to describe the steps that they went through in order to address the initial problem presented in the lesson. They were further asked if they had completed all the activities in the learning environment and if they could think of any activity which could have been done in a different way.

1.6.6 Procedure

The implementation lasted for three class meetings. In the first meeting (80 minutes), each condition completed pre-tests and undertook a familiarization activity with the tools and the virtual lab to be used, in a different context (weather) than the one encountered later on in the ILS (electrical circuits). Students were instructed explicitly about how to formulate a hypothesis in the form of an “if…then…” statement. Then they had the opportunity to create their own hypotheses regarding how weather would affect children’s decision to play indoors or outdoors. Students were also explicitly taught the VOTAT strategy (“Vary One Thing At a Time”; also referred to as the “control-of-variables” strategy – CVS), in order to execute fair experiments, and they tried to set up a fair experiment for the hypotheses they had previously formulated in the weather context. VOTAT is a heuristic in designing experiments, where manipulating one independent variable at a time allows learners to attribute any change in the dependent variable to the independent variable which was manipulated (Glaser, Schauble, Raghavan, & Zeitz, 1992; Lin & Lehman, 1999; Tsirgi, 1980; Klahr, & Nigam, 2004; Veermans, van Joolingen & de Jong, 2006). A demonstration of the Electrical Circuit Lab followed, where each student had the opportunity to create several circuits in the lab.

In the second meeting (80 minutes), students went through the ILS. Attention was paid to time-on-task effects so that participants in each condition spent about the same time to accomplish the entire learning activity sequence. The teacher mainly provided technical support to students when it was necessary; for instance, when students had accidentally exited the learning environment, the teacher would assist them with re-entering the ILS. For content-specific issues, the recommendation to students was to go through the instructions and hints included in the learning environment. In the third meeting (50 minutes), students in every condition used the HS and the EDT to formulate hypotheses and design experiments, respectively, in two new learning contexts. The first context was about rolling marbles in an inclined ramp and the second context addressed the solubility of sugar in water.

1.6.7 Data collection and analyses

Assessment of students' prior knowledge and inquiry skills involved two different instruments administered in a pre-test format. The knowledge test consisted of four items, which corresponded to three cognitive processes termed “remember”, “understand” and “apply”, based on the revised Bloom’s (1956) taxonomy, as presented by Anderson and Krathwohl (2001) and further elaborated in the reports edited by de Jong (2014) and Zervas (2013). For the inquiry skills test, items included in the TIPSII were selected and translated into Greek (Burns et al., 1985). The inquiry skills test consisted of 5 multiple-choice items, where 3 items referred to “identifying and stating hypothesis”, and another 2 items referred to “designing investigations”. The selection of TIPSII items was based on the appropriateness of wording and content in relation to student age. Both tests were scored blind to the students' assigned condition. A rubric was used for evaluation of the open-ended items on the knowledge test, and two independent coders scored 20% of the data. The inter-rater agreement between the coders was found to be high (Cohen’s Kappa = 0.87).

Apart from pre-tests, computer screen-captured data were collected for all students during the completion of the ILS (second meeting) and during the activities in the new learning contexts (third meeting) by means of RiverPast software. Data analysis of this material focused on the learning products constructed by students as they progressed along the learning activity sequence (see in this regard Hovardas, 2016). We concentrated on students' hypotheses, students' experimental designs, correspondence of students' hypotheses with their experimental designs, and correspondence of students' use of the virtual laboratory with their experimental designs. All the variables referring to software scaffolds and learning products constructed by students during the learning activity sequence are shown in Table 16. Coding schemes for scoring learning products were developed and two coders independently rated 10% of each category of learning products. Inter-rater reliability (proportion of agreement) amounted to over 85% across all categories, while divergences between raters were settled through discussion.

We used non-parametric tests and analyses to investigate trends in data, which involved *Kruskal-Wallis* tests, *Mann-Whitney* tests, *Wilcoxon* two-related samples tests, and *Spearman’s* rank correlations. We also performed a correspondence analysis to examine the relative weight of each variable studied across conditions.

Table 16. Variables referring to software scaffolds and learning products during the learning activity sequence.

Variable code	Description of variable and values	Measure	Range
ScoreHypo	Maximum score across hypotheses formulated by students in the ILS; “0” = no dependent variable included or invalid dependent variable (i.e., one that cannot be tested in the Electrical circuit lab); “1” = valid dependent variable but missing or invalid independent variable; “2” = valid dependent and independent variable	Scale	0-2
EDT_VOTAT	VOTAT strategy implemented in the ILS; “0” = no implementation; “1” = partial implementation; “2” = full implementation (e.g., across all hypotheses)	Scale	0-2
EDT_Trials	Experimental trials planned in the ILS; “0” = no planning; “1” = partial planning; “2” = full planning (at least two trials were planned for each hypothesis)	Scale	0-2
HS_EDT	Correspondence between hypotheses and experimental designs in the ILS; “0” = no correspondence; “1” = partial correspondence; “2” = full correspondence (e.g., across all hypotheses)	Scale	0-2
EDT_Trials_Lab	Correspondence between experimental designs and circuits in the lab in the ILS; “0” = no correspondence; “1” = partial correspondence; “2” = full correspondence (e.g., across all trials)	Scale	0-2
postScoreHypo	Maximum score across hypotheses formulated by students in the new learning contexts; “0” = no dependent variable included or invalid dependent variable (i.e., one that cannot be tested in the provided labs); “1” = valid dependent variable but missing or invalid independent variable; “2” = valid dependent and independent variable	Scale	0-2
postEDT_VOTAT	VOTAT strategy implemented in the new learning contexts; “0” = no implementation; “1” = partial implementation; “2” = full implementation (e.g., for both novel contexts)	Scale	0-2
postEDT_Trials	Experimental trials planned in the new learning contexts; “0” = no planning; “1” = partial planning; “2” = full planning (e.g., for both novel contexts)	Scale	0-2
postHS_EDT	Correspondence between hypotheses and experimental designs in the new learning contexts; “0” = no correspondence; “1” = partial correspondence; “2” = full correspondence (e.g., for both novel contexts)	Scale	0-2

Note: HS = Hypothesis Scratchpad; EDT = Experiment Design Tool; ILS = Inquiry Learning Space; VOTAT = Vary-One-Thing-At-a-Time.

1.6.8 Results

Research question 1: Separate effect of each tool

It presents mean values for all variables studied, by assigned condition and learning context. An overview of the table indicates that there were significant differences among conditions in most cases (i.e., in both the learning activity sequence and the new learning contexts). More specifically, conditions providing one of the two tools outperformed the condition with no tools in the corresponding skill pertaining to that tool. With regard to student performance when working in the ILS, students who used the HS only (Condition 2; HS only) scored higher for their hypotheses (Table 17; "ScoreHypo") than students who did not use this tool (Condition 4; no tool) (*Mann-Whitney* $Z = -2.73$, $p < 0.01$). Additionally, students who used the EDT only (Condition 3; EDT only) showed increased implementation of the VOTAT heuristic (Table 17; "EDT_VOTAT"), compared to students who did not use this tool (Condition 4; no tool) (*Mann-Whitney* $Z = -4.12$, $p < 0.001$).

Research questions 2 and 3: Combined effect of both tools; inter-contextual transferability of learning gains

The combined effect of both tools seems to have outweighed the effect of each tool separately in the new contexts provided to students for experimentation after they concluded activities in the ILS. This was especially evident in the case of formulating hypotheses (Table 17; "postScoreHypo") (*Mann-Whitney* $Z = -2.05$, $p < 0.05$, for the difference between Conditions 1 and 2; *Mann-Whitney* $Z = -3.16$, $p < 0.01$, for the difference between Conditions 1 and 3), planning experimental trials (Table 17; "postEDT_Trials") (*Mann-Whitney* $Z = -3.18$, $p < 0.01$, for the difference between Conditions 1 and 2; *Mann-Whitney* $Z = -2.48$, $p < 0.05$, for the difference between Conditions 1 and 3) and the correspondence between student hypotheses and experimental designs (Table 17; "postHS_EDT") (*Mann-Whitney* $Z = -2.26$, $p < 0.05$, for the difference between Conditions 1 and 2; *Mann-Whitney* $Z = -2.81$, $p < 0.01$, for the difference between Conditions 1 and 3).

Overall, the condition that employed both tools (Condition 1; HS+EDT) showed increased scores for most of the studied variables in the new learning contexts, namely, the new contexts given to students after they had exited the ILS, in comparison to the values recorded in the ILS (Table 17). This finding provides an indication that the beneficial effect of software scaffolding increased across learning contexts for Condition 1. The opposite can be observed for the other three conditions, where students scored lower across all variables in the new learning contexts as compared to the ILS. However, *Wilcoxon* two-related-samples tests revealed that there were no significant time trends for any condition from the ILS to the new learning contexts.

Table 17. Mean values of variables studied, by condition and learning context.

	Condition[1]				
	HS and EDT	HS only	EDT only	No tool	[2]*Kruskal-Wallis* χ^2
Learning Activity Space					
ScoreHypo	1.73	1.82	1.22	1.00	11.69**
EDT_VOTAT	1.45	0.00	2.00	0.00	35.32***
EDT_Trials	1.73	0.75	1.44	0.67	10.95*
HS_EDT	1.36	0.83	0.56	0.67	5.09ns
EDT_Trials_Lab	1.73	1.08	1.22	0.67	10.03*
New learning contexts					
postScoreHypo	2.00	1.42	0.67	0.78	12.90**
postEDT_VOTAT	1.55	0.00	1.33	0.00	30.57***
postEDT_Trials	1.82	0.67	0.89	0.44	13.90**
postHS_EDT	1.27	0.50	0.22	0.38	11.11*

1: HS = Hypothesis Scratchpad; EDT = Experiment Design Tool; all values range between 0 (min) and 2 (max)
2: ns = non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Research question 4: Correlations among hypotheses, experimental designs, and execution of experiments in the virtual lab

Scores for the condition with both tools (Condition 1) showed significant correlations among various parameters studied. Hypothesis scores correlated positively with correspondence of hypotheses and experimental designs (*Spearman's rho* = 0.74, $p < 0.05$), while planning of experimental trials correlated positively with correspondence of student use of the virtual laboratory with their experimental designs (*Spearman's rho* = 0.98, $p < 0.001$). Another significant correlation was between planning experimental trials and employing the VOTAT heuristic in the new learning contexts (*Spearman's rho* = 0.71, $p < 0.05$). No such correlations were found in the other conditions. All of these results offer a strong indication that for Condition 1 (HS+EDT), student competence on a learning task could have positively catalyzed performance on forthcoming learning tasks in either the ILS or in the new learning contexts.

Research question 5: Relative weight of variables studied across conditions

We performed a correspondence analysis in order to investigate which variables were most closely linked to the conditions to which students had been assigned. The biplot of the analysis is shown in **Error! Reference source not found.**. Overall, the closer a variable is to a c ondition, the more that condition shows increased values of that variable, as compared to the other conditions. On the positive part of the first axis we can observe that Condition 3 (EDT only) is related to the implementation of the VOTAT heuristic in the ILS as well as in the new learning contexts ("EDT_VOTAT" and "postEDT_VOTAT", respectively). On the negative part of the first axis, Condition 2 (HS only) is characterized by relatively increased scores for hypotheses in both the ILS and the new learning contexts ("ScoreHypo" and "postScoreHypo", respectively). Condition 1 (HS + EDT) features in the negative part of the second axis and it is distinguished by a marked correspondence between hypothesis formulation and experimental designs in the new learning context ("postHS_EDT") as well as by increased validity in planning experimental trials in the new learning contexts ("postEDT_Trials"). The relative position of conditions and variables on the biplot implies that each tool separately fostered performance on learning tasks related to its scaffolding properties. Namely, the HS reinforced student ability to adequately formulate hypotheses, while the EDT enhanced student competence in implementing the VOTAT heuristic. Indeed, this was the case in the learning context of the ILS as well as in the new learning contexts. The condition that combined both tools (Condition 1; HS + EDT) seems to have been marked by relatively increased inter-contextual transfer as well as inter-task transferability of learning gains, which took the form in the new learning contexts of relatively increased validity in planning experimental trials and a close correspondence between students' hypotheses and their experimental designs.

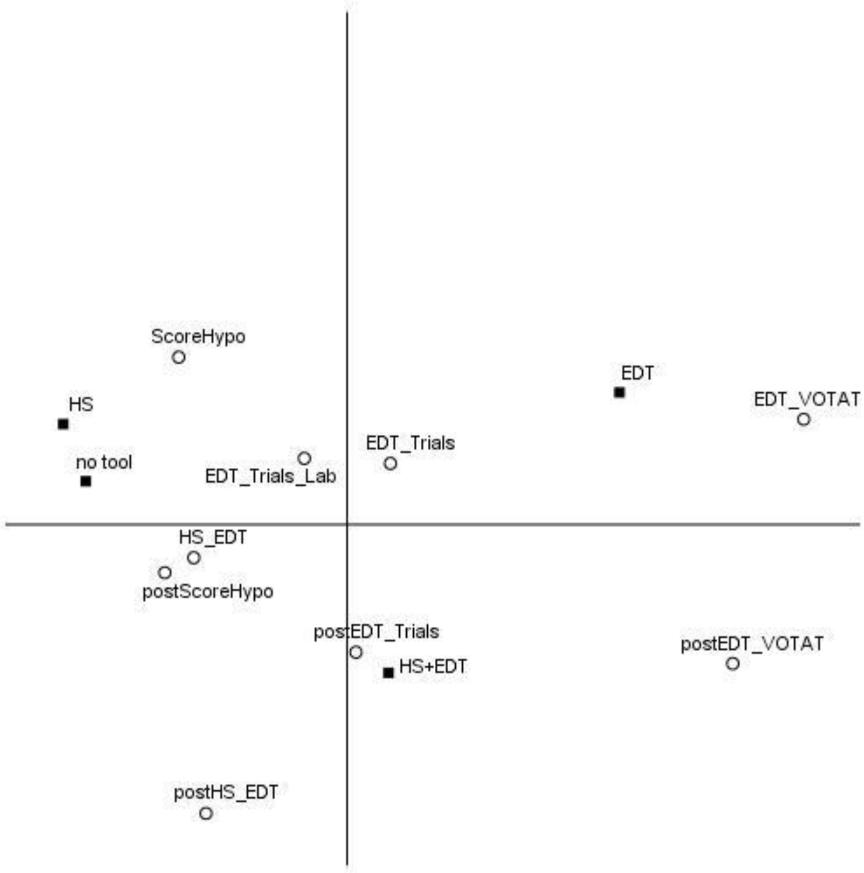


Figure 25. Bi-plot of correspondence analysis depicting variables studied (white circles: ScoreHypo; EDT_VOTAT; EDT_Trials; HS_EDT; EDT_Trials_Lab; postScoreHypo; postEDT_VOTAT; postEDT_Trials; postHS_EDT) and conditions (black boxes: HS + EDT; HS; EDT; no tool). Overall, the closer a variable is to a condition, the more this condition is characterized by increased values of this variable, as compared to the other conditions. The first axis accounted for 88% of total variance, while the second axis added another 11%.

1.6.9 Discussion

A first major result of our study was that each software scaffold separately succeeded in supporting students in the corresponding learning tasks, which addressed our first research question. Such an encouraging finding must be attributed to the design and properties of each tool. Further, it implies that both tools may have adequately handled the two contrasting needs of structuring student inquiry on the one hand, and problematizing student work, on the other. An explanation for that delicate and balanced contribution might be that both tools were fairly effective in offering procedural information to students, namely, information on what students should do and how they should address the corresponding learning tasks (see, for instance, Arnold et al., 2014). A related explanation might refer to the tools' allowance for serial processing of learning tasks (see, for instance, the VOTAT strategy that was related to the use of the EDT), where the complexity in a learning activity sequence might be addressed by partitioning tasks into smaller-scale, shorter assignments that need to be dealt with one after the other (Clarke, Ayres, & Sweller, 2005; Pollock, Chandler, & Sweller, 2002). Such a serial processing of learning tasks might have kept essential cognitive load within the limits that learners could manage based on their cognitive capacity and the processing limitations of working memory (Kalyuga, 2007; Sweller, van Merrienboer, & Paas, 1998). It might also have kept students alert and motivated to encounter upcoming tasks, which could have adequately touched upon the dimension of problematizing student inquiry.

With regard to our second research question, the results presented in this paper indicated that students using both tools benefited more as compared to students who used one tool only. This finding is a clear sign of a combined effect, where the impact of both software scaffolds might have outweighed the impact of each tool separately. Concerning our third research question, the combined effect of tool usage was also detected in new inquiry contexts, which is a strong indication of inter-contextual transfer of skill gains. An additional combined effect was implied by significant correlations among studied parameters in the condition that incorporated both tools (fourth research question). These correlations indicate that using both tools might not only increase the corresponding skills separately (i.e., formulating hypotheses and designing experiments) but that it might also result in skill gains that spread across learning tasks as the learning activity sequence unfolds. Namely, skill gains in formulating hypotheses might pass on to designing experiments and the latter might pass on to handling a virtual lab. Although previous research may have indicated such a linkage (e.g., Arnold et al., 2014; Veermans, van Joolingen, & de Jong, 2006), our results offer the first empirical validation of this transfer. We should highlight that our results imply that transfer could involve two different scales. The first addresses transition between different contexts (inter-contextual transfer), while the second is anchored within a single learning activity sequence and refers to gains being transferred from a learning task to a forthcoming learning activity (inter-task transfer). Results concerning transfer were further validated by our correspondence analysis (fifth research question).

Another major point that needs to be discussed is the fact that the current study focused on learning products, namely, artifacts produced by students themselves during a learning activity sequence, instead of relying on instruments administered in pre-test post-test formats. The concentration on learning products enabled the elaborate investigation of transfer effects as discussed above, as far as both inter-contextuality and interrelation between learning tasks is concerned. Previous research has highlighted the benefits of storing, retrieving, and exchanging learning products in computer-supported inquiry learning environments (e.g., de Jong et al., 2010, 2012). It has also stressed the potential of using learning products for diagnosing student performance and enacting formative assessment (e.g., Hovardas, 2016). Since students might not be offered numerous opportunities to reflect on their work during inquiry learning (Hofstein & Lunetta, 2003), elaboration on learning products might strengthen the metacognitive aspect of learning environments considerably, and might be especially insightful in subsequent cycles of inquiry. At this point, it should be taken into account that learning products stored during a learning activity sequence designed in a computer-supported learning environment might themselves serve as scaffolds either during upcoming activities or when encountering new learning contexts. All these directions would be fruitful avenues for future research.

Future research could also use learning products to investigate additional functionalities, which software scaffolds could carry out. For example, the HS can include varying numbers of words (variables involved in the phenomenon under study plus conditionals necessary to interrelate variables) to support students in formulating hypotheses. Varying the number of words provided to students might be a way to vary the degree of scaffolding the HS offers to students, perhaps with fading of the scaffolding as learners gain experience. This would mean that the HS could include fewer words for more experienced learners (see in this regard Kalyuga & Sweller, 2004; Reisslein, Atkinson, Seeling, & Reisslein, 2006; Seufert & Brünken, 2006). In the case of the EDT, fading in and out of scaffolding could involve the number of variables offered to students to design their experiments. Since most analogous tools in computer-supported learning environments are delivered in a "one-for-all fashion" (Kalyuga, 2007), future research might screen optimal timing for introducing and removing scaffolding, as well as varying of scaffolding based on student experience and competence (see, for instance, de Jong, 2006). If learners proceed effectively in a learning activity sequence even after scaffolding has been removed, this would provide a substantial indication that the scaffolded skill has been acquired. Future research might further examine possible effects on cognitive load and demands on working memory imposed by different scaffolding configurations for tools.

1.6.10 References

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

Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding students' experiments - What kind of support do they need in inquiry tasks? *International Journal of Science Education, 36*, 2719-2749.

Bloom, B. S. (1956). *Taxonomy of educational objectives. Handbook I: The cognitive domain*. New York: David McKay.

Burns, J., Okey, J., & Wise, K. (1985). Development of an integrated process skill test: TIPS II. *Journal of Research in Science Teaching, 22*, 169-177.

Chang, K.-E., Chen, Y.-L., Lin, H.-Y., & Sung, Y.-T. (2008). Effects of learning support in simulation-based physics learning. *Computers and Education, 51,* 1486-1498.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175-218.

Clarke, T., Ayres, P., & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. *Educational Technology Research and Development, 53*, 15-24.

De Boer, G. E., Quellmalz, E. S., Davenport, J. L., Timms, M. J., Herrmann-Abell, C. F., Buckley, B. C., Jordan, K. A., Huang, C.-W., & Flanagan, J. C. (2014). Comparing three online testing modalities: Using static, active, and interactive online testing modalities to access middle school students' understanding of fundamental ideas and use of inquiry skills related to ecosystems. *Journal of Research in Science Teaching, 51*, 523-554.

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

de Jong, T. (Ed.). (2014). *Preliminary inquiry classroom scenarios and guidelines. D1.3. Go-Lab Project (Global Online Science Labs for Inquiry Learning at School).* http://www.go-lab-project.eu/sites/default/files/files/deliverable/file/Go-Lab%20D1.3.pdf

de Jong, T., Sotiriou, S., & Gillet, D. (2014). Innovations in STEM education: the Go-Lab federation of online labs. *Smart Learning Environments, 1*, 1-16.

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68*, 179-201.

de Jong, T., van Joolingen, W. R., Giemza, A., Girault, I., Hoppe, U., Kindermann, J., Kluge, A., Lazonder, A. W., Vold, V., Weinberger, A., Weinbrenner, S., Wichmann, A., Anjewierden, A., Bodin, M., Bollen, L., d´Ham, C., Dolonen, J., Engler, J., Geraedts, C., Grosskreutz, H., Hovardas, T., Julien, R., Lechner, J., Ludvigsen, S., Matteman, Y., Meistadt, Ø., Næss, B., Ney, M., Pedaste, M., Perritano, A., Rinket, M., von

Schlanbusch, H., Sarapuu, T., Schulz, F., Sikken, J., Slotta, J., Toussaint, J., Verkade, A., Wajeman, C., Wasson, B., Zacharia, Z. C., & van der Zanden, M. (2010). Learning by creating and exchanging objects: the SCY experience. *British Journal of Educational Technology, 41*, 909-921.

de Jong, T., Weinberger, A., van Joolingen, W.R., Ludvigsen, S., Ney, M., Girault, I., Kluge, A., Lazonder, A., Pedaste, M., Wasson, B., Wichmann, A., Geraedts, C., Hovardas, T., Julien, R., Lejeune, A., Manoli, C., Matteman, Y., Sarapuu, T., Vold, V., Wanders, B., & Zacharia, Z. (2012). Designing complex and open learning environments based on scenarios. *Educational Technology Research & Development, 60*, 883-901.

Furtak, E. M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education, 90*, 453-467.

Germann, P. J., Aram, A., & Burke, G. (1996). Identifying patterns and relationships among the responses of seventh-grade students to the science process skill of designing experiments. *Journal of Research in Science Teaching, 33*, 79-99.

Glaser, R., Schauble, L., Raghavan, K., & Zeitz, C. (1992). Scientific reasoning across different domains. In E. De Corte, M. Linn, H. Mandl, & L. Verschaffel (Eds.), *Computer-based learning environments and problem solving* (pp. 345–373). Berlin: Springer-Verlag.

Govaerts, S., Cao, Y., Vozniuk, A., Holzer, A., Zutin, D. G., Ruiz, E. S. C., Bollen, L., Manske, S., Faltin, N. Salzmann, C., Tsourlidaki, E., & Gillet, D. (2013). Towards an online lab portal for inquiry-based STEM learning at school. In J.-F. Wang & R. Lau (Eds.), *Advances in web-based learning – ICWL 2013, 12th International Conference, Kenting, Taiwan, October 6-9, 2013, Proceedings* (pp. 244-253). Berlin: Springer.

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*, 28-54.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching, 42*, 791-806.

Hovardas, T. (2016). A learning progression should address regression: Insights from developing non-linear reasoning in ecology. *Journal of Research in Science Teaching*, DOI: 10.1002/tea.21330.

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*, 509-539.

Kalyuga, S., & Sweller, J. (2004). Measuring knowledge to optimize cognitive load factors during instruction. *Journal of Educational Psychology, 96*, 558-568.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*, 75-86.

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: effect of direct instruction and discovery learning. *Psychological Science, 15*, 661-667.

Koksal, E. A., & Berberoglou, G. (2014). The effect of guided inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education, 36*, 66-78.

Kremer, K., Specht, C., Urhahne, D., & Mayer, J. (2014). The relationship in biology between the nature of science and scientific inquiry. *Journal of Biological Education, 48*, 1-8.

Lin, X., & Lehman, J. D. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. *Journal of Research in Science Teaching, 36*, 837-858.

Minner, D. D., Jurist Levy, A., & Century, J. (2010). Inquiry-based science instruction – What is it and does it matter? Results from a research synthesis years 1984-2002. *Journal of Research in Science Teaching, 47*, 474-496.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences, 13*, 423-451.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*, 61-86.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences, 13*, 273-304.

Reiser, B. J., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., & Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver & D. Klahr (Eds.), *Cognition and instruction: Twenty-five years of progress* (pp. 263-305). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Reisslein, J., Atkinson, R. K., Seeling, P., & Reisslein, M. (2006). Encountering the expertise reversal effect with a computer-based environment on electrical circuit analysis. *Learning and Instruction, 16*, 92-103.

Roberts, R., & Gott, R. (2003). Assessment of biology investigations. *Journal of Biological Education, 37*, 114-121.

Rodríguez-Triana, M. J., Holzer, A., Vozniuk, A., & Gillet, D. (2015). Orchestrating inquiry-based learning spaces: An analysis of teacher needs. In F. W. B. Li, R. Klamma, M. Laanpere, J. Zhang, B. F. Manjón, & R. W. H. Lau (Eds.), *Advances in web-based learning -- ICWL 2015, 14th International Conference, Guangzhou, China, November 5-8, 2015, Proceedings* (pp. 131-142). Cham, Switzerland: Springer.

Seufert, T., & Brünken, R. (2006). Cognitive load and the format of instructional aids for coherence formation. *Applied Cognitive Psychology, 20*, 321-331.

Simons, K. D., & Klein, J. D. (2007). The impact of scaffolding and student achievement levels in a problem-based learning environment. *Instructional Science, 35*, 41-72.

Sweller, J., van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*, 251-296.

Tsirgi, J. E. (1980). Sensible reasoning: A hypothesis about hypotheses. *Child Development, 51*, 1-10.

van Joolingen, W. R. (1999). Cognitive tools for discovery learning. *International Journal of Artificial Intelligence in Education, 10*, 385-397.

van Joolingen, W. R., & de Jong, T. (1991). Supporting hypothesis generation by learners exploring an interactive computer simulation. *Instructional Science, 20*, 389-404.

van Joolingen, W. R., & Zacharia, Z. C. (2009). Developments in inquiry learning. In N. Balacheff, S. Ludvigsen, T. de Jong, & S. Barnes (Eds.), *Technology-enhanced learning* (pp. 21-37). Dordrecht, The Netherlands: Springer.

Veermans, K., van Joolingen, W. R., & de Jong, T. (2006). Use of heuristics to facilitate scientific discovery learning in a simulation learning environment in a physics domain. *International Journal of Science Education, 28*(4), 341-361.

Zacharia, Z. C., Manoli, C., Xenofontos, N., de Jong, T., Pedaste, M., van Riesen, S. A. N., Kamp, E. T., Mäeots, M., Siiman, L., & Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Educational Technology Research and Development, 63*, 257-302.

Zervas, P. (Ed.). (2013). *The Go-Lab inventory and integration of online labs – labs offered by large scientific organisations. D2.1. Go-Lab Project (Global Online Science Labs for*

Inquiry Learning at School). http://www.go-lab-project.eu/sites/default/files/files/deliverable/file/Go-Lab-D2.1.pdf

1.7 *Study 7: Unravelling hidden assumptions in virtual laboratories: A strategy of designing model-based science inquiry in computer-supported learning environments.*

Tasos Hovardas1, Marcus Pedaste2, Zacharias Zacharia1, Ton De Jong3
1: University of Cyprus, 2: University of Tartu; 3: University of Twente

The proposed chapter will present a pedagogical design for addressing model-based science inquiry in computer-supported learning environments. Specifically, we will build on the need to familiarize students with basic structural as well as operational requirements of creating inquiry oriented learning trajectories while using online laboratories, both virtual and remote, within the context of the Go-Lab platform (http://www.go-lab-project.eu/). Moreover, we will provide an insight for the possibilities of providing proper guidance at any stage of the inquiry process in an attempt to support the students in their inquiry endeavours.

A question that is raised at this point is, how these inquiry based learning trajectories should be designed in order for the students to have a fruitful and effective learning experience? In order to answer this question, we ground our arguments on the Pedaste et al. (2015) inquiry framework, which describes two alternative trajectories through an inquiry cycle. The first pathway focuses on exploration of the phenomenon under study, whereas the second pathway concentrates on hypothesis formulation and experimentation, when students would have already become familiar with the studied topic. Inherent in the contradistinction between these two alternative trajectories is a time dimension. Namely, students would first need to become familiar with the phenomenon under study (i.e., explore basic variables and core dimensions of the phenomenon), and, then, in a subsequent inquiry cycle, they might proceed to a more elaborate examination, where they would be able to formulate hypotheses and test their hypotheses through experimentation. We will argue in the proposed chapter that this two-step procedure is necessary for designing model-based inquiry in computer-supported learning environments. For example, such learning arrangements often include virtual labs, where natural phenomena might have been modelled. If students simulate these phenomena without having first explored the models, on which their experimentation would need to be based, a series of assumptions concerning variables in the model, model behavior as well as core model assumptions might remain latent, unattended and unaccounted for. In this regard, student experimentation might unfold in a trial-and-error basis and it would largely depend on data generation and the interaction with the interface offered by the virtual laboratory. However, the ability of students to critically revise the phenomena modelled might have been seriously compromised.

A way out of this undesired bottleneck would be to design two subsequent inquiry cycles in the sequence which has been described above, namely, a first exploratory cycle and a second cycle which would involve experimentation. In the terminology employed in the project Go-Lab, this would take the form of two subsequent Inquiry Learning Spaces, which would include all necessary inquiry phases of the two alternative pathways. Namely, the first Inquiry Learning Space would incorporate a comprehensive exploration of the phenomenon under study, which would primarily involve the identification of all necessary variables for constructing a baseline model of the phenomenon. This first encounter of students with the scientific model would let them familiarize with core assumptions and specifications concerning variable interaction in the model and it would present an introduction to the virtual laboratory which would be used later on to simulate the modeled phenomenon. In that vein, the second Inquiry Learning Space would include the virtual laboratory based on the scientific model. In that latter inquiry cycle, students would have the opportunity to simulate the phenomenon in the virtual lab.

In the frame of model-based inquiry, we might revisit the well-reported controversy between structuring student work, on the one hand, and problematizing student inquiry, on the other. Specifically, the first Inquiry Learning Space might offer a substantial opportunity to structure student work, namely, to identify all core variables that are involved in the phenomenon under study and build a basic model. The second Inquiry Learning Space might problematize student inquiry by challenging them with a variation or extension of the phenomenon that would not be readily addressed by means of the baseline model. In this regard, student work would be organized around the necessary changes and revisions needed to the baseline model so as to address the challenge.

Further, the design we have outlined would necessitate a corresponding adjustment of software scaffolds so as to support student inquiry. This support would need to be adequately aligned to either exploratory or experimental inquiry cycles. For instance, the first Inquiry Learning Space might incorporate a Concept Mapper (http://www.golabz.eu/content/go-lab-concept-mapper), a Concept Cloud (http://www.golabz.eu/apps/conceptcloud), a Quiz Tool (http://www.golabz.eu/apps/quiz-tool), and a Question Scratchpad (http://www.golabz.eu/apps/question-scratchpad), so that students would reflect on their prior knowledge and process core reference material. In an analogous manner, the second Inquiry Learning Space might involve a Hypothesis Scratchpad (http://www.golabz.eu/app/hypothesis-tool), an Experiment Design Tool (http://www.golabz.eu/apps/experiment-design-tool), and a Data Viewer (http://www.golabz.eu/apps/data-viewer), so that students would be assisted during their experimentation.

Our design approach would have a series of implications for formative assessment and inter-contextual transfer. For instance, formative assessment might be based on learning products constructed by students along their learning trajectories. Teachers might need to concentrate on important aspects of a number of learning products so that they could be ready to diagnose student performance and provide timely feedback. This formative assessment strategy might be accompanied by the interplay of agents embedded in the learning platform, which could point to divergence from desired student behavior. For instance, terms used by students in the Concept Mapper, or the Hypothesis Scratchpad might refer to misconceptions and alert teachers or the system itself to adopt their intervention accordingly. Concerning inter-contextual transfer, subsequent cycles of model-based inquiry are expected to present numerous opportunities to students for implementing knowledge and skills acquired during a former inquiry cycle to learning activities undertaken later on along their inquiry.

1.8 Study 8: “Problematizing” scientific inquiry by synergies of software scaffolds: The effect of time-on-task and navigation on student performance.

Nikoletta A. Xenofontos1, Tasos Hovardas1, Zacharias C. Zacharia1, Ton de Jong2

1Research in Science and Technology Education Group
Department of Educational Sciences
University of Cyprus
P. O. Box 20537, Nicosia 1678, Cyprus
Tel.: + 357 22 892957, Fax: + 357 22 486999, Email: zach@ucy.ac.cy

2Faculty of Behavioral Sciences
University of Twente, Enschede 7500AE, Netherlands
E-mail: a.a.anjewierden@gw.utwente.nl

[This paper presents an extension of Chapter 11 (Constructing graphs by means of the Data Viewer: Comparison between two different configurations of the tool in terms of their effects on student knowledge and skills) of Deliverable D8.3 ((First trial report)) and has been submitted to Interactive Learning Environments]

1.8.1 Abstract

We developed two architectural designs, based on different synergies of software scaffolds. These designs presented alternative ways to problematize students with a graphing task. We followed student navigation and performance after they were confronted with this task. The learning activity sequence involved experimentation with a virtual lab. Our results indicated that both designs would problematize students by inducing retrospective action but they would lead to different navigation patterns. Data analyses implied a complementary functioning of time-on-task and retrospective action. There seems to be a minimum quantity of time needed to effectively execute tasks during scientific inquiry. When lesser time than this boundary had been spent in the learning activity sequence, the remainder would be devoted to working with tools during retrospective action, in order to conclude basic requirements of designing or executing an experiment. We also found a threshold, after which working in the lab would be detrimental for learning. In terms of implications for science education and inquiry learning, our study demarcates a novel field of research, namely, the one related to trade-offs between time-on-task and retrospective action, which would be realizable only within computer-supported learning environments. Our results provide insight for configuring learner-tailored feedback in computer-supported learning environments.

Keywords

Learning products; problematizing; retrospective action; scientific inquiry; software scaffolds; time-on-task

1.8.2 Introduction

A challenge for designing and assessing software scaffolds has always been to strike a balance between two contrasting needs, namely, structuring student work, on the one hand, and “problematizing” students, on the other (Reiser, 2004). Structuring would be needed to manage complex, open-ended tasks. At the same time, instruction would need to problematize students at some points along their learning trajectories to re-allocate their attention to insightful actions, which would promote student knowledge and skills (Pea, 2004; Reiser, 2004). Such a re-orientation would be a prerequisite for deeper understanding. Whereas structuring student work would simplify tasks and reduce complexity, problematizing would add complexity to direct students to productive pathways. The controversy between structuring and problematizing has been an unresolved issue in inquiry learning, in terms of how much scaffolding, guidance and support is to be offered to students (Arnold, Kremer, & Mayer, 2014; Koksal & Berberoglou, 2014; Minner, Jurist Levy, & Century, 2010). If there is too much guidance, then learners would not be adequately challenged; if more degrees of freedom are provided than students can handle, then goals of inquiry learning would remain largely unattainable (e.g., Chang, Chen, Lin, & Sung, 2008).

The design and assessment of software scaffolds in science education has largely concentrated on their structuring effects (Saye & Brush, 2002; Simons & Klein, 2007; Zacharia, Manoli, Xenofontos, et al., 2015). For instance, tools developed to scaffold experimental design have often incorporated a heuristic, which directs students towards varying one thing (i.e., independent variable) at a time (i.e., VOTAT heuristic or strategy) (Chang, Chen, Lin, & Sung, 2008; Veermans, van Joolingen, & de Jong, 2006; Zacharia et al., 2015). The basic idea in this heuristic is that by changing values for one variable at a time, one can follow its effects on the dependent variable and design a fair experiment. Compared to the primary focus of software design on structuring student tasks, the potential for problematizing students and balancing structuring against problematizing has been rather underresearched (Reiser, 2004). Further, exploration and assessment of aid offered by software scaffolds has largely concentrated on separate tools embedded in learning environments (see for an extensive review Zacharia et al., 2015). Our aim in the present study was to investigate effects on student navigation and performance after problematizing students along a learning activity sequence that involved two different architectures of software scaffolds.

The activity sequence employed in this study was designed on the basis of core components of an inquiry cycle, namely, of a number of interrelated steps that are essential for students to conclude a scientific inquiry (Pedaste, Mäeots, Siiman, et al., 2015). A complete inquiry cycle in science education has to involve a set of standard learning activities to be undertaken so that a scientific investigation would be carried out. For instance, tasks to be conducted during an experimentation would include identification of variables and formulation of hypotheses, the development of an experimental design, the execution of an experiment, data collection, organization and analyses, and finally, data interpretation (Harwood, 2004; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Kremer, Specht, Urhahne, & Mayer, 2014). All these tasks comprise a phase in scientific inquiry, which has been termed “investigation phase” (Pedaste et al., 2015). Students face difficulties in executing tasks in the investigation phase (de Jong, 2006), even in secondary education (Arnold, Kremer, & Mayer, 2014; De Boer, Quellmalz, Davenport, et al., 2014; Furtak, 2006; Kirschner, Sweller, & Clark, 2006). Therefore, this phase is the one that has involved most support by software scaffolds in inquiry learning (Zacharia et al., 2015).

In this exemplification of scientific inquiry, it is obvious that former tasks feed in into following tasks. Namely, an experimental design would need to be aligned to the hypotheses that had been formulated previously. Further, the execution of an experiment has to follow the steps prescribed in the experimental design, while data organization and analyses would be based on data gathered during the investigation phase. While going through an inquiry cycle, students would have to carry along learning products they had constructed in previous tasks so that they would be able to respond to new tasks. In terms of instruction, a learning activity sequence would equate to a sequence of learning products manufactured all along an inquiry cycle, where learning products coming out of previous activities would be used as necessary input for learning activities to be undertaken later on. In terms of software design, learning products need to be stored so that students can retrieve them and work with them to undertake a forthcoming learning activity. Learning products offer valuable insight for monitoring student behaviour and performance (Hovardas, in press) and this might have a series of implications for computer-supported learning environments. The construction of learning products in scientific inquiry reiterates the controversy between structuring and problematizing. When learning products are too difficult for students to construct, then students employ trial-and-error strategies, which need to occupy a quite extensive capacity of working memory. A learning product, on the other hand, which would be easily constructed, would leave much cognitive capacity unaccounted for. The ideal situation would be that the task presented to learners would challenge them just above their current expertise (Kalyuga, 2007).

In the present study we examined student navigation and performance along a learning activity sequence embedded in a computer-supported learning environment. Students prepared and executed an experimentation and, at some point in their inquiry, they would need to construct a graph using a graphing tool and data they had collected earlier while they had been working in a virtual lab. We used two different configurations of the graphing tool, which presented two different contexts of balancing structuring and problematizing. In the first configuration, students were given the dependent variable of the graph to be constructed and they would need to select a second variable to plot. In this configuration, students were offered lesser variables than needed to construct their graph. In the second configuration, students were given a set of four different variables, out of which they would need to select two variables to construct their graph. In this configuration, students were offered more variables than needed to construct their graph. In each case, students were assisted up to a degree since the graphing tool structured the task of graph construction. Students would need to take a decision, though, before completing the task. In that regard, they were "problematized", which would either involve the identification of an independent variable, in the first configuration, or screening among variables, in the second configuration of the graphing tool. The main objective of our exploratory study was to compare student navigation and performance between the two configurations, which included (1) analysing learning products constructed by students in each configuration, (2) investigating student behaviour before and after they had been presented the graphing task, namely how they would navigate in the learning environment before and after being "problematized" (3) examining correlations among parameters of student performance and behaviour within each configuration, and (4) determining properties of learning products or student behaviour, which predicted student knowledge and skill gains.

1.8.3 Methods

The study was undertaken within the frame of the Go-Lab project (http://www.go-lab-project.eu/). We designed a computer-supported learning environment with a concentration on science experimentation and developed two different configurations of the same design, which diverged only in one connection among software scaffolds. In the first configuration, the graphing tool embedded in the environment (Data Viewer) loaded data from a virtual lab (Electrical Circuit Lab). In this case, the graphing tool offered students the dependent variable to construct their graphs and students had to identify a second variable to plot. In the second configuration, the graphing tool loaded data from a software scaffold that guided experimental design (Experiment Design Tool). In this latter case, the graphing tool offered students four different variables to construct their graphs. The students had to select and plot two out of these four variables.

1.8.4 Participants

The study involved 25 tenth graders (16-17 years old; 13 boys and 12 girls) from two classes of two public senior high schools (Lyceums) in Larnaca, Cyprus. Students in the first class (11 students) worked with the first configuration of the learning environment (i.e., Data Viewer linked to the Electrical Circuit Lab). Students in the second class (14 students) worked with the second configuration (i.e., Data Viewer linked to the Experiment Design Tool). All students had advanced computer skills and were of same ability. Prior knowledge and skills did not differ between the two classes (see Data sources). It should be noted that the sample was purposefully kept small because of the amount of data we wanted to collect and analyse through several data sources per participant. In other words, the emphasis was on data richness rather than on sample size. We collected data from different data sources that provided considerable depth and were complementing each other in order to shape a holistic picture of student behaviour and performance. Moreover, this was an investigative in nature study, which was looking for possible patterns and relationships by “feeding” the analyses with as more potentially related variables as possible.

1.8.5 Learning environment

Our learning environment focused on electrical circuits connected in series and in parallel. We created an Inquiry Learning Space, which includes all phases of a typical inquiry process (see Pedaste et al., 2015), using the Go-Lab authoring tool (de Jong, Sotiriou, & Gillet, 2014). Students formulated hypotheses in the Hypotheses Scratchpad (http://www.golabz.eu/app/hypothesis-tool), they prepared their experimental designs by means of the Experiment Design Tool (http://www.golabz.eu/apps/experiment-design-tool), they constructed electrical circuits in the Electrical Circuit Lab (Figure 27; http://www.golabz.eu/lab/electrical-circuit-lab), they recorded their observations using the Observation Tool (http://www.golabz.eu/apps/observation-tool), they constructed their graphs by means of the Data Viewer (http://www.golabz.eu/apps/data-viewer), and they interpreted their graphs in the Input Box (http://www.golabz.eu/apps/input-box). The entire learning activity sequence, where this study focuses on, is depicted in Figure 28.

We differentiated between two architectural configurations, which involved two different conditions of the Data Viewer. In the first condition, students stored records of electric current in their experimental trials by means of the Data collector, which had been embedded in the Electrical Circuit Lab. When students were ready to use the Data Viewer, data stored in the Data collector were available to them through the ammeter, which was depicted in the Data set container of the Data Viewer (Figure 29). Since there was only one variable available to students, they had to create a new variable in the Data set container of the Data Viewer to be able to construct a graph. This was done by them manually and had to be based on observations and notes taken previously. After students created the second variable, they had to drag both variables from the Data set container to the graph space to plot them. In the second configuration of the Data Viewer, all variables included in the Experiment Design Tool were automatically transferred to the Data set container of the Data Viewer (Figure 30). These variables were “number of bulbs”, “setup”, “voltage”, and “electric current”. Values for all variables had to be saved by students after each experimental trial in the Experiment Design Tool, to be automatically retrieved afterwards. In this second condition, students would need to choose two out of four variables to plot. Whereas the first condition of the Data Viewer was based on a link with the Electrical Circuit Lab, the second condition was linked to the Experiment Design Tool.

The Experiment Design Tool segmented the complex task of designing an experiment into a set of sub-tasks to be processed serially (e.g., Clarke, Ayres, & Sweller, 2005; Pollock, Chandler, & Sweller, 2002; Kalyuga, 2007). This involved classification of variables in dependent, independent and controlled variables and then scheduling experimental trials based on the former classification. This would be a necessary order of actions for conducting a valid experiment (e.g., Chinn & Malhotra, 2002; Marschner, Thillmann, Witrth, & Leutner, 2012; Roberts & Gott, 2003). Feedback was provided by the tool to students anytime they misclassified variables so that students would realize their divergence from optimal learning pathways and monitor their performance (e.g., Marschner, Thillmann, Witrth, & Leutner, 2012). The tool also maintained values for control variables in subsequent experimental trials and directed student attention to values of other variables that needed to be handled. This automated function was meant to offload aspects of the task, decrease task complexity, and re-allocate student effort (e.g., Reiser, 2004). After students had conducted their experiments in the virtual lab, they returned to the Experiment Design Tool to enter the value of the dependent variable. They had to do this for each one of their experimental trials.

In the Electrical Circuit Lab (virtual lab), students were offered various components to construct electrical circuits in alignment to their experimental designs. Observations in the lab and data interpretations after graph construction were based on a series of questions that acted as prompts (Appendix 1). Students would need to screen observations in the lab or their inspections of graphs to select crucial information so as to address these questions by means of the Observation Tool. Finally, graph construction in the Data Viewer presupposed that students would need to either identify the second variable to construct their graphs (first configuration of the tool) or to select the appropriate variables out of a set of four variables provided to them (second configuration of the tool). Interpretation of graphs was also guided by a series of questions which students addressed by using the Input Box (Appendix 1). Overall, questions were designed to address production deficiency, namely, to let students reflect upon information or heuristics they might dispose of but which might not be employed spontaneously (Veenman, van Hout-Wolters, & Afflerbach, 2006).

1.8.6 Procedure

The implementations were undertaken by the science teachers of the classes that participated in our study. Before the implementation, both teachers took part in a face-to-face preparatory meeting to become familiarized with the learning environment, arrange technical requirements for infrastructure, and elaborate on the role of the teacher in each lesson. Teacher guidance was kept minimum so that we would track student behaviour and performance along the learning activity sequence under no instructional support apart from the support offered by the learning environment itself. However, teachers would assist students in overcoming technical problems, e.g., anytime there was a delay in tool loading. Overall, such technical issues had been circumstantial and did not distract students from their tasks.

Each implementation involved four class meetings of 40 minutes each. The first meeting covered pre-tests (see next section). The next two meetings occurred in the computer lab of each school, so that each student would be able to work in a computer. The teacher briefly introduced the learning environment and then let students go through the learning activities. The last meeting was dedicated to post-tests.

1.8.7 Data sources and data analyses

We used two tests to assess student knowledge and graph interpretation skill. The knowledge test was based on a revision of Bloom's (1956) taxonomy of educational objectives by Anderson and Krathwohl (2001) and it was further elaborated by de Jong (2014) and Zervas (2013) (Appendix 2). It was pilot tested for validity (expert panel of three PhD graduates in science education) and reliability (sample of 30 tenth graders who were not further involved in this study; Cronbach's alpha = 0.82), after which adjustments were made in wording and two items were deleted. We used a rubric to score open ended items in the knowledge test. The inter-rater agreement between two independent coders (first two authors) for 20% of data was good (Cohen's Kappa = 0.93). The knowledge test was used once again after the implementation to assess knowledge gains. For assessing the graph interpretation skill prior to the implementation, we used items in the graph interpretation factor that were included in the TIPSII instrument (Burns, Okey & Wise, 1985). Both tests were scored blind to the configuration of the learning environment to which each student had been assigned.

Learning products constructed by students along the learning activity sequence were stored in the learning environment and they were retrieved and analysed. We used a coding procedure for outlining properties of learning products which should be profiled and logged (Appendix 3).

Additionally, we recorded student behaviour using computer screen capture software (i.e., River Past Screen Recorder Pro). In this case, we focused on student behaviour after students were presented the problematizing task in the Data Viewer, which induced retrospective action. Namely, students returned to the Electrical Circuit Lab or to the Experiment Design Tool to validate their routes and rework their learning products, if needed (Appendix 4). We also calculated total time spent by students in retrospective action after they reached the Data Viewer. For both coding processes (learning products and screen captured data), a coding scheme was first developed and used by the second author to code data. The first author used the same coding scheme to code 10% of data referring to learning products and another 10% referring to data on student behaviour. This was done to measure inter-rater reliability. Cohen's Kappa was higher than 0.87 across all data categories. All divergences were settled through discussion between coders.

Concerning time-on-task, it was measured as time devoted by students to working on the Experiment Design Tool and the Electrical Circuit Lab. We used a fine-grained approach and observed screen captured data to distinguish on-task from off-task actions (e.g., time spent on a website other than the one hosting the Inquiry Learning Space of the implementation) (see for instance Cohen, Manion, & Morrison, 2007). The latter were subtracted from time-on-task.

We used non-parametric tests to compare student behaviour and performance between the two different configurations of the learning environment (Chi-square and Mann-Whitney tests). The Spearman's rho correlation coefficient was calculated to investigate correlations among parameters of student behaviour within each configuration. Finally, we performed tree analysis to identify significant predictors of student performance, namely, student knowledge and graph interpretation skill. Knowledge measures were given by subtracting scores in the post-test from scores in the pre-test (i.e., knowledge improvement). The graphing interpretation skill that served as the dependent variable in our analyses was assessed by means of student responses to three questions that were included in the learning environment and acted as prompts (see Appendix 1 and Appendix 3, last row). All analyses have been performed with SPSS 21.

1.8.8 Results

Differences between conditions in properties of learning products

No statistical significant difference was found between conditions in properties of learning products (Appendix 3). Additionally, there was no difference in knowledge improvement and graph interpretation skill. Overall, these findings indicate that the two configurations of software scaffolds did not diverge in terms of their effect on student performance.

Differences between conditions in student behaviour after they reached the Data Viewer

There were significant differences in student behaviour after they were confronted with the problematizing task in the Data Viewer (Table 18). Almost all students in the second configuration returned to the Experiment Design Tool and spent there more extra time than students in the first configuration (about 5 times as much). Total time spent during retrospective action was also higher in the second condition (almost twice as much as students in the second configuration). All these differences reveal that the second configuration (Data Viewer linked to the Experiment Design Tool) was related to more retrospective action after students reached the Data Viewer. For both conditions, extra time spent on the Experiment Design Tool increased when students reworked their learning products in this tool (Mann-Whitney $Z = -2.67$; $p < 0.01$, for students in the first condition, and Mann-Whitney $Z = -3.00$; $p < 0.01$, for students in the second condition).

Correlations among parameters of retrospective action in each condition

Table 19 and Table 20 present Spearman's rho correlation coefficients calculated for parameters of retrospective action in the first and second condition, respectively. Overall, we need to highlight that time spent on either the Experiment Design Tool or the Electrical Circuit Lab within the learning activity sequence (i.e., EDTTime and LABTime, respectively) was negatively correlated to time spent on working with the Experiment Design Tool or the Electrical Circuit Lab during retrospective action (i.e., ExtraTimeEDT and ExtraTimeLAB, respectively). Negative coefficients were statistically significant in the conditions engaging the corresponding applications. Namely, in the first condition (i.e., Data Viewer linked to the Electrical Circuit Lab), the more time students had spent in the Electrical Circuit Lab in the learning activity sequence, the lesser time they would spent in the lab during retrospective action (Table 19; Spearman's rho = -0.62; $p < 0.05$). Further, in the second condition (i.e., Data Viewer linked to the Experiment Design Tool), the more time students had spent in the Experiment Design Tool in the learning activity sequence, the lesser time they would spent in the same tool during retrospective action (Table 20; Spearman's rho = -0.64; $p < 0.05$). Another finding was that time-on-task, including the time spent during retrospective action, was positively correlated across tools/applications processed serially. This indicates that student effort was conveyed across applications needed to perform an experimentation. However, this trend was only significant for retrospective action in the second condition, where extra time spent on the Experiment Design Tool was positively correlated to extra time spent on the Electrical Circuit Lab (Table 20; Spearman's rho = 0.79; $p < 0.01$).

Predictors of knowledge improvement and graph interpretation skill in each condition

Figure 31 and Figure 32 present tree models for knowledge improvement and the graph interpretation skill (dependent variables) in the first and second condition, respectively. All properties of learning products and aspects of student behaviour (Appendices 3 and 4) were included in the analysis as independent variables (predictors). Trees include only significant predictors. Reading the trees from top to end nodes, we can follow the effect of predictors on dependent variables. For the first condition (Data Viewer linked to the Electrical Circuit Lab), knowledge improved more when students spent more than 216 seconds in revisiting the Electrical Circuit Lab (Figure 31; first split of three, right branch). If students devoted lesser time than this threshold in the lab (Figure 31; first split of three, left branch) during retrospective action, then their knowledge improvement was mediated by the number of hypotheses they had formulated while going through the learning activity sequence. An increased number of hypotheses did not favour improvement of knowledge (Figure 31; second split of three, right branch), which implies that an increased complexity in learning tasks might hinder improvement in student performance. With regard to graph interpretation (Figure 31), there were two predictors related to the Experiment Design Tool. Employing the VOTAT (Vary-One-Thing-At-a-Time) strategy (first split) and time-on-task spent on the Experiment Design Tool (second split) fostered graph interpretation. Time-on-task spent in the Electrical Circuit Lab was a significant predictor for knowledge improvement and graph interpretation in the second condition (Data Viewer linked to the Experiment Design Tool). In both cases, however, these effects were negative, after a threshold, on dependent variables. Specifically, working in the virtual lab for more than 316 seconds would impair knowledge gains (Figure 32, first split, right branch), while working in the lab for more than 239 seconds would weaken graph interpretation (Figure 32, first split, right branch). Overall, time-on-task in the virtual lab and the tool for designing experiments featured as the most pronounced predictors of student performance. However, the effect of time-on-task was positive for the Experiment Design Tool but negative, after a threshold value, for the Electrical Circuit Lab. Retrospective action did not coexist together with time-on-task among predictors.

1.8.9 Discussion

The architectural designs employed in the present study utilized two different linkages of software scaffolds. In the first configuration, the Data Viewer was linked to the Electrical Circuit Lab, while the second configuration connected the Data Viewer to the Experiment Design Tool. Although these two conditions did not differ significantly in terms of student performance (i.e., properties of learning products, knowledge, graph interpretation), they induced different student behaviour in terms of retrospective action. The second design was characterized by more time devoted to retrospective action, which might be attributed to the earlier position of the Experiment Design Tool in the learning activity sequence as compared to the Electrical Circuit Lab. Indeed, revisiting the Experiment Design Tool in the second configuration was accompanied by also revisiting the Electrical Circuit Lab, which was not observed as a statistical significant correlation in the first configuration. This latter finding was another indication of the influence of architecture and the learning activity sequence on retrospective action. Overall, our results indicate that the two different architectural designs would both problematize students but they would lead to different student navigation in the learning environment. Although students were not aware of these linkages, they were directed towards revisiting the facilities that would allow them to validate their routes and re-work their learning products. Previous studies revealed that time devoted to tasks is linked to student judgments concerning time allocation (e.g., Metcalfe & Finn, 2008; Thiede, Anderson, & Therriault, 2003). Future research should shed more light on how problematizing students is related to allocating additional time among various options during retrospective action. Our study revealed that focusing on learning products and student navigation as well as on synergies among software scaffolds, instead of assessing each tool separately, would be fruitful in that regard.

Although the second condition presented more retrospective action, this backward navigation featured among predictors of student performance only in the first condition. This might suggest that retrospective action would not readily translate in learning gains. Although extra time spent on the Experiment Design Tool was significantly increased when students re-worked their learning products, this has not proven beneficial for student knowledge or skills. On the contrary, revisiting the virtual lab fostered student knowledge, which might denote that retrospective action on different applications might trigger different metacognitive effects. The time dimension has been underlined as a crucial factor for determining metacognition in technology-enhanced learning in science education (Yıldız-Feyzioğlu, Akpınar, & Tatar, 2015). Metacognition was moreover associated to self-regulation of learning (Fiorella, Vogel-Walcutt, & Fiore, 2012). Future research might delve deeper in this direction and employ additional research instruments to examine heterogeneous metacognitive effects caused by alternative designs. Investigating differences between novices and more knowledgeable learners would be also insightful in this regard (Hofstein & Lunetta, 2003; Kalyuga & Sweller, 2004; Reisslein, Atkinson, Seeling, & Reisslein, 2006; Reisslein, Sullivan, & Reisslein, 2007; Seufert & Brünken, 2006).

More research is also needed to differentiate metacognitive effects between time-on-task during a learning activity sequence as opposed to additional time allocated to learning tasks during retrospective action. Correlations and tree models in our analyses implied a complementary functioning of retrospective action and time-on-task. Correlations indicated that there seems to be a minimum quantity of time needed to effectively execute tasks during scientific inquiry, for instance, in working with the Experiment Design Tool or in the Electrical Circuit Lab. When lesser time than this temporal boundary had been spent in the learning activity sequence, then the remainder would need to be devoted to working with the tool during retrospective action, in order to conclude basic requirements of designing or executing an experiment. These findings re-iterate the importance of time-on-task in fulfilling learning tasks, which has been frequently underlined (e.g., Karweit & Slavin, 1982; Slavin, 2014). However, not all time-on-task would be beneficial for student knowledge or skills, as we have observed in the case of the Electrical Circuit Lab. Although computer-supported learning environments might optimize quality time spent on learning tasks, there were numerous indications that a negative influence of technology on student attention cannot be singled out, for instance when students are confronted with a multiplicity of tasks (e.g., Bowman, Waite, & Levine, 2015). Since extra time on the lab during retrospective action had a positive effect on knowledge, future research might examine in more detail the influence of time allocated during serial processing of learning activities versus the effect of time allocation during retrospective action. It could be, for instance, that retrospective action together with its potential metacognitive benefits would be beneficial only when a negative threshold existed during serial processing of learning tasks, after which time-on-task would hinder learning progress.

In terms of implications for science education and inquiry learning, our study demarcates a novel field of research, namely, the one opened up by trade-offs between time-on-task and retrospective action, which would be realizable only within computer-supported learning environments. Problematizing students by adequately configuring the architecture of these environments might initiate retrospective action, which could prove beneficial for student performance, if planned accordingly. Previous research has approached inquiry more or less in a sequential manner, taking the serial succession of learning activities as a basic design for students to follow (see for instance Minner, Jurist Levy, & Century, 2010). Although it had been indicated as a possible pathway (e.g., Pedaste et al. 2015), retrospective action has remained an unexplored alternative for students, educators and software developers. Our results implied that retrospective action might contribute substantially to achieving learning objectives, especially when adequate time had not been devoted to working on certain tasks and software scaffolds during the serial processing of learning activities. Returning to previous tasks could be a possibility in computer-supported learning environments, which might add significantly in promoting student knowledge. What is more, retrospective action introduces new horizons for designing inquiry learning as long as it might offer novel options to develop learning progressions, for instance, a desirable backward navigation to learning tasks which have already been handled. This return would have been treated in the past as subsidiary to straight forward progression. Our research shows, however, that returning to tasks already processed might be constructive for accomplishing learning gains.

The results of our study might provide valuable insight for configuring feedback in computer-supported learning environments. Specifically, the number of hypotheses formulated by students might be tracked and lead to varying feedback to students based on decision trees. For instance, when learners would face an increased complexity during retrospective action (i.e., the need to handle multiple hypotheses, which had been formulated earlier in the learning activity sequence), then they might be instructed to select and focus on one hypothesis only. Two aspects should be highlighted in this regard. First, choosing proper timing to provide instructional support might be crucial for learning (Pol, Harskamp, & Suhre, 2008). Further, agents scheduled for computer-supported learning environments need to relate to various instances of learner behaviour, navigation, and performance in order to be able to introduce or remove support. These notifications would be an example of how to handle the delicate balance between structuring student work, on the one hand, and “problematizing” students, on the other. Software scaffolds would allow educators to proceed to specifications for increasing structuring when problematizing would prove unproductive as well as for presenting challenges and problematizing students when this would foster their performance. Such a development would assist in addressing the gap of diagnosing student behaviour and performance in order to offer constructive and timely feedback and build learner-tailored environments (see for instance Kalyuga, 2007). Apart from quantitative indicators, qualitative indicators of student behaviour could also be monitored, e.g., whether students have implemented the VOTAT heuristic or not. Overall, the potential of providing feedback to learners needs to be investigated and linked to formative assessment enacted on the basis of student interaction with software tools and on the basis of the opportunities that are available to monitor student progression along a learning activity sequence. Such a direction for future research would be quite valuable for educators to design their instruction as long as technology would allow them to spare precious time by taking over part of their current tasks.

1.8.10 References

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

Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding students' experiments - What kind of support do they need in inquiry tasks? *International Journal of Science Education, 36*, 2719-2749. DOI: 10.1080/09500693.2014.930209.

Bloom, B. S. (1956). *Taxonomy of educational objectives. Handbook I: The cognitive domain*. New York: David McKay.

Bowman, L. L., Waite, B. M., & Levine, L. E. (2015). Multitasking and attention. In L. D. Rosen, N. A. Cheever, & L. M. Carrier (Eds.), *The Wiley Handbook of Psychology, Technology, and Society* (pp. 388–403). Chichester, UK: John Wiley & Sons, Ltd. DOI:10.1002/9781118771952.ch22.

Burns, J., Okey, J., & Wise, K. (1985). Development of an integrated process skill test: TIPS II. *Journal of Research in Science teaching*, 22, 169-177. DOI: 10.1002/tea.3660220208.

Chang, K.-E., Chen, Y.-L., Lin, H.-Y., & Sung, Y.-T. (2008). Effects of learning support in simulation-based physics learning. *Computers and Education*, 51, 1486-1498. DOI: 10.1016/j.compedu.2008.01.007.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86, 175–218. DOI: 10.1002/sce.10001.

Clarke, T., Ayres, P., & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. *Educational Technology Research and Development*, 53, 15–24. DOI: 10.1007/BF02504794.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th edition). London/New York: Routledge.

De Boer, G. E., Quellmalz, E. S., Davenport, J. L., Timms, M. J., Herrmann-Abell, C. F., Buckley, B. C., Jordan, K. A., Huang, C.-W., & Flanagan, J. C. (2014). Comparing three online testing modalities: Using static, active, and interactive online testing modalities to access middle school students' understanding of fundamental ideas and use of inquiry skills related to ecosystems. *Journal of Research in Science Teaching*, 51, 523-554. DOI: 10.1002/tea.21145.

de Jong, T. (2006). Computer simulations – Technological advances in inquiry learning. *Science*, 312, 532–533. DOI: 10.1126/science.1127750.

de Jong, T., (Ed.). (2014). *Preliminary inquiry classroom scenarios and guidelines. D1.3. Go-Lab Project* (Global Online Science Labs for Inquiry Learning at School).

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, 68, 179-201. DOI: 10.3102/00346543068002179.

de Jong, T., Sotiriou, S., & Gillet, D. (2014). Innovations in STEM education: the Go-Lab federation of online labs. *Smart Learning Environments*, 1, 1-16. DOI: 10.1186/s40561-014-0003-6.

Fiorella, L., Vogel-Walcutt, J. J., & Fiore, S. (2012). Differential impact of two type of metacognitive prompting provided during simulation-based training. *Computers in Human Behavior*, 28, 696–702. DOI:10.1016/j.chb.2011.11.017.

Furtak, E. M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, 90, 453–467. DOI: 10.1002/sce.20130.

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88, 28-54. DOI: 10.1002/sce.10106.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching*, 42, 791–806. DOI: 10.1002/tea.20072.

Hovardas, T. (in press). A learning progression should address regression: Insights from developing non-linear reasoning in ecology. *Journal of Research in Science Teaching*, in press.

Kalyuga, S. (2007). Expertise reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review, 19*, 509-539. DOI: 10.1007/s10648-007-9054-3.

Kalyuga, S., & Sweller, J. (2004). Measuring knowledge to optimize cognitive load factors during instruction. *Journal of Educational Psychology*, 96, 558–568. DOI: 10.1037/0022-0663.96.3.558.

Karweit, N., & Slavin, R. E. (1982). Time-on-task: Issues of timing, sampling, and definition. *Journal of Educational Psychology*, 74, 844–851. http://dx.doi.org/10.1037/0022-0663.74.6.844.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41, 75–86. DOI: 10.1207/s15326985ep4102_1.

Koksal, E. A., & Berberoglou, G. (2014). The effect of guided inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education*, 36, 66-78. DOI: 10.1080/09500693.2012.721942.

Kremer, K., Specht, C., Urhahne, D., & Mayer, J. (2014). The relationship in biology between the nature of science and scientific inquiry. *Journal of Biological Education*, 48, 1–8. DOI: 10.1080/00219266.2013.788541.

Marschner, J., Thillmann, H., Witrth, J., & Leutner, D. (2012). Wie lässt sich die Experimentierstrategie-Nutzung fördern? Ein Vergleich verschiedener gestalteter Prompts. *Zeitschrift für Erziehungswissenschaft*, 15, 77-93. DOI: 10.1007/s11618-012-0260-5.

Metcalfe, J., & Finn, B. (2008). Evidence that judgments of learning are causally related to study choice. *Psychonomic Bulletin & Review*, 15, 174-179. DOI: 10.3758/PBR.15.1.174.

Minner, D. D., Jurist Levy, A., & Century, J. (2010). Inquiry-based science instruction – What is it and does it matter? Results from a research synthesis years 1984-2002. *Journal of Research in Science Teaching*, 47, 474-496. DOI: 10.1002/tea.20347.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences*, 13, 423–451. DOI: 10.1207/s15327809jls1303_6.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. DOI: 10.1016/j.edurev.2015.02.003.

Pol, H. J., Harskamp, E. G., & Suhre, Cor J. M. (2008). The effect of the timing of instructional support in a computer-supported problem-solving program for students in secondary physics education. *Computers in Human Behavior*, 24, 1156–1178. DOI: 10.1016/j.chb.2007.04.002.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction*, 12, 61–86. DOI: 10.1016/S0959-4752(01)00016-0.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences,* 13, 273-304. DOI: 10.1207/s15327809jls1303_2.

Reisslein, J., Atkinson, R. K., Seeling, P., & Reisslein, M. (2006). Encountering the expertise reversal effect with a computer-based environment on electrical circuit analysis. *Learning and Instruction*, 16, 92–103. DOI: 10.1016/j.learninstruc.2006.02.008.

Reisslein, J., Sullivan, H., & Reisslein, M. (2007). Learner Achievement and Attitudes under Different Paces of Transitioning to Independent Problem Solving. *Journal of Engineering Education*, *96*, 45-56. DOI: 10.1002/j.2168-9830.2007.tb00914.x.

Roberts, R., & Gott, R. (2003). Assessment of biology investigations. *Journal of Biological Education*, 37, 114–121. DOI: 10.1080/00219266.2003.9655865.

Saye, J. W. & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, 50, 77–96. DOI: 10.1007/BF02505026.

Seufert, T., & Brünken, R. (2006). Cognitive load and the format of instructional aids for coherence formation. *Applied Cognitive Psychology*, 20, 321–331. DOI: 10.1002/acp.1248.

Simons, K. D., & Klein, J. D. (2007). The impact of scaffolding and student achievement levels in a problem-based learning environment. *Instructional Science, 35*, 41-72. DOI: 10.1007/s11251-006-9002-5.

Slavin, R. E. (2014). *Educational psychology: Theory and practice* (11th edition). Boston: Pearson Education.

Thiede, K.W., Anderson, M. C. M., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology*, 95, 66-73. DOI: 10.1037/0022-0663.95.1.66.

Veenman, M. V. J., van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and Learning*, 1, 3–14. DOI: 10.1007/s11409-006-6893-0.

Veermans, K., van Joolingen, W. R., & de Jong, T. (2006). Use of heuristics to facilitate scientific discovery learning in a simulation learning environment in a physics domain. *International Journal of Science Education, 28*(4), 341-361. DOI: 10.1080/09500690500277615.

Yıldız-Feyzioğlu, E., Akpınar, E., & Tatar, N. (2015). Monitoring students' goal setting and metacognitive knowledge in technology-enhanced learning with metacognitive prompts. *Computers in Human Behavior*, 29, 616–625. DOI: 10.1016/j.chb.2012.11.019.

Zacharia, Z. C., Manoli, C., Xenofontos, N., de Jong, T., Pedaste, M., van Riesen, S. A. N., Kamp, E. T., Mäeots, M., Siiman, L., & Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Educational Technology Research and Development, 63*, 257-302. DOI: 10.1007/s11423-015-9370-0.

Zervas, P. (Ed.). (2013). *The Go-Lab inventory and integration of online labs – labs offered by large scientific organisations*. D2.1. Go-Lab Project (Global Online Science Labs for Inquiry Learning at School).

Appendix 1. Prompts embedded in the learning environment

Prompts in the Observation tool

Each time you conduct an experimental trial in the Electrical Circuit Lab, you need to record the values of variables tested and you also need to keep notes in the Observation Tool on the following aspects:

-How would you compare the brightness of the bulbs in each circuit?

- Is the brightness of the bulbs the same with the brightness of the bulb in a simple electric circuit?

Prompts in the Input Box for graph interpretation

The following questions will help you to interpret your graphs.

- What is the effect of adding bulbs in a circuit on the electric current? Please try to support your reasoning by referring to your data.

- How does the brightness of the bulbs change when adding bulbs in series? What happens when adding bulbs in parallel?

- Please consider that the brightness of a bulb is an indicator of the electric current that flows through it. How does the electric current that flows through each bulb change, when adding bulbs in series, and when adding bulbs in parallel?

Appendix 2. The knowledge test

Name: ______________________________

School name: ______________________________

Date: ______________________________

Age: ______________________________

Gender: ______________________________

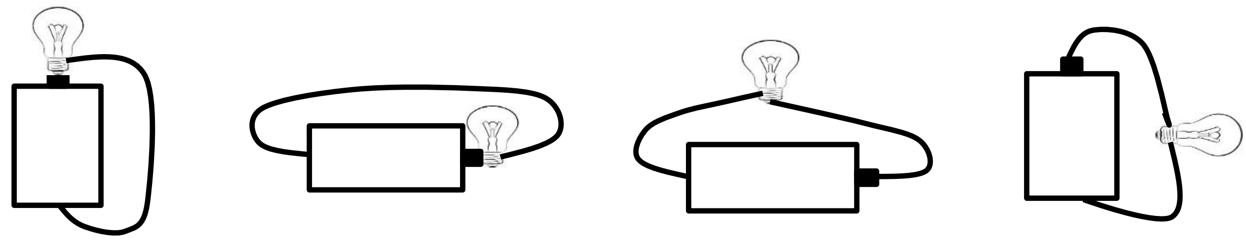
NOTE:

In order to complete this test you will need approximately 20 minutes. You have to answer to all items (1-6). The results of this test will not count to your total score in the lesson. They will be used anonymously for research purposes.

1. Which components are necessary to create a simple electric circuit? Describe how these components must be connected.

____

2. In which of the following the bulb will light up? Please choose one answer.



A) B) C) D)

a) A and B

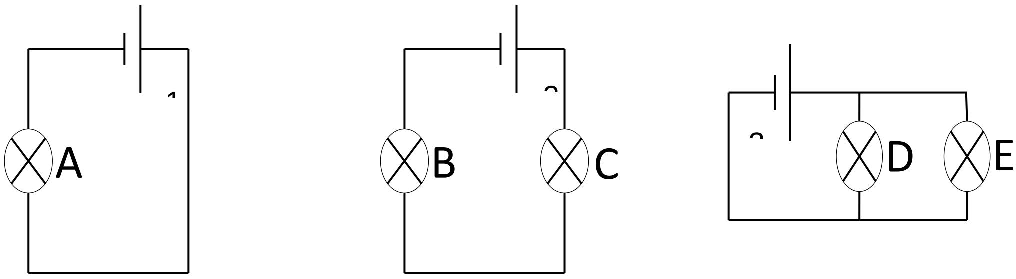
b) A and C

c) C and D

d) All of them

e) None of them

3. Look at the following circuits:



3.1. How does the brightness of the bulbs compare? Please choose one answer.

a) A > B = C = D = E

b) A < B = C < D = E

c) D = E = A > B = C

d) B = C = A < D = E

e) A > D = E < B = C

3.2 Which are the differences between 1, 2, and 3, with regard to the electric current that flows through each circuit? Please choose one answer.

a) 1 = 3 > 2

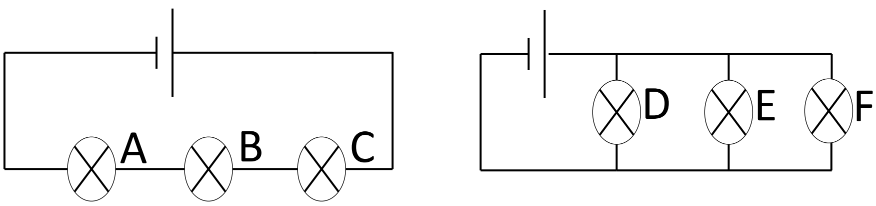
b) 1 < 2 = 3

c) 2 = 3 < 1

d) 2 < 1 < 3

e) 1 = 2 < 3

4. What will happen if the middle bulb burns out (and it is not removed from the circuit)? Please choose one answer.



a) A and C do not light, D and F light equally

b) All the bulbs (A, C, D and F) do not light

c) A and C light equally but less than D and F, which light equally

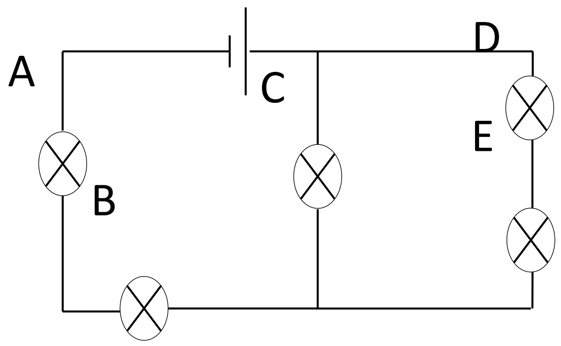
d) All the bulbs (A, C, D and F) do light

e) D and F do not light, A and C light equally

5. What do the multiple electrical sockets, used for the operation of multiple electrical appliances, imply about the type of the connection? Please explain your reasoning.

___

6. How does the brightness of the bulbs compare in the following circuit? Please explain your reasoning.



Appendix 3. Variables processed for each learning activity along the learning activity sequence

Learning activity	Variable (Name of variable as it appears in the Results section); Values for variable	Measure	Range (min-max)
Formulate hypotheses	Number of hypotheses formulated (NumberHypo); Count	Scale	0-2
	Maximum score of hypotheses (ScoreHypoMax); "0" = no dependent variable included or invalid dependent variable (i.e., one that cannot be tested in the Electrical Circuit Lab); "1" = valid dependent variable but missing or invalid independent variable; "2" = valid dependent and independent variable	Scale	0-2
Design an experiment	Time-on-task working with the Experiment Design Tool in seconds (EDTTime); Count	Scale	28-535
	Number of pop-up windows that appeared when using EDT (EDTFeedback); Count	Scale	0-5
	VOTAT strategy (EDTVOTAT); 0/1	Binary	0-1
	Number of experimental trials planned (Trials); Count	Scale	0-5
	Values of variables in at least one experimental trial (ValuesTrialsRecorded): 0/1	Binary	0-1
Execute an experiment	Time-on-task working with the Electrical Circuit Lab in seconds (LABTime); Count	Scale	125-1126
	Number of circuits created (Circuits); Count	Scale	0-6
	Data selected by operating at least one circuit (DataVCircuitRecorded): 0/1	Binary	0-1
Make observations	Number of observations recorded by the Obervation Tool (NumberObserv); Count	Scale	0-2
	Maximum score across all observations (ScoreObservMax): "0" = no dependent variable mentioned or invalid dependent variable (i.e., one that was not tested in the Electrical Circuit Lab); "1" = valid dependent variable but missing or invalid independent variable; "2" = valid dependent and independent variable	Scale	0-2
Construct graphs	Number of graphs created by the Data Viewer (NumberGraphs); Count	Scale	0-2
	Graphs included valid dependent and independent variables (GraphCorrectness); 0/1	Binary	0-1
	At least an independent variable in one Graph was invalid (GraphIncorrect_IND); 0/1	Binary	0-1
	At least a dependent variable in one Graph was invalid (GraphIncorrect_DEP); 0/1	Binary	0-1
Interpret graphs	Number of valid inferences (GraphInter); Count	Scale	0-6; recalculated to range between 0 and 1

Appendix 4. Variables processed for activities undertaken during restrospective action (after reaching the Data Viewer)

Activity undertaken	Variable (Name of variable as it appears in the Results section); Values for variable	Measure	Range (min-max)
Revisit the Experiment Design Tool	Return to the Experiment Design Tool (ReturnEDT); 0/1	Binary	0-1
	Construct new learning products with the Experiment Design Tool (ActionReturnEDT_NLP); 0/1	Binary	0-1
	Extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT); Count	Scale	0-372
Revisit the Electrical Circuit Lab	Return to the Electrical Circuit Lab (ReturnLAB); 0/1	Binary	0-1
	Construct new learning products with the Electrical Circuit Lab (ActionReturnLab_NLP); 0/1	Binary	0-1
	Extra time spent on the Electrical Circuit Lab in seconds (ExtraTimeLAB); Count	Scale	0-771
Total time spent during retrospective action	Total time spent during retrospective action after reaching the Data Viewer (TotalTimeReturn); Count	Scale	0-993

Figure legends

Figure 27. The Electrical Circuit Lab (http://www.golabz.eu/lab/electrical-circuit-lab).

Figure 28. The learning activity sequence, where the study focuses on. Learning activities are depicted in rectangles and learning products in rhombuses. In each activity, students construct learning products, which are needed as input in forthcoming activities. This is depicted by means of connections among activities and rhombuses. Dashed connections and rhombuses depict potential student behavior in retrospective action, after they had encountered the problematizing task in the Data Viewer.

Figure 29. The first configuration of the Data Viewer (http://www.golabz.eu/apps/data-viewer). The Data Viewer was linked to the Electrical Circuit Lab.

Figure 30. The second configuration of the Data Viewer (http://www.golabz.eu/apps/data-viewer). The Data Viewer was linked to the Experiment Design Tool.

Figure 31. Tree model with predictors of knowledge improvement (A) and graph interpretation skill (B) of students in the first condition (Data Viewer linked to the Electrical Circuit Lab). Dependent variables are shown at the top of the tree (Node 0; KnowImprove; GraphInter) and they have been rescaled to range between 0 and 1. Indepepdent variables (predictors) are shown at each split: extra time spent on the Electrical Circuit Lab in seconds (ExtraTimeLAB) and number of hypotheses formulated (NumberHypo) for knowledge improvement; VOTAT (Vary-One-Thing-At-a-Time) strategy (EDTVOTAT) and time-on-task working with the Experiment Design Tool in seconds (EDTTime) for the graph interpretation skill. The CRT (Classification and Regression Trees) method has been used to grow the tree. The method partitions the data in homogeneous segments with respect to the dependent variable. At each split, the predictor variable is shown together with a statistic, which presents the improvement in the tree from the parent to the child node. At each brannch of a split (i.e., left and right branch), the tree presents the threshold of the predictor variable, according to which the partitioning of the student sample has taken place. Each node presents mean value (equals to predicted) and standard deviation of the dependent variable, number of students (n) and their precentage in the student sample. Total variance explained for A = 90.66% and B = 74.46%.

Figure 32. Tree model with predictors of knowledge improvement (A) and graph interpretation skill (B) of students in the second condition (Data Viewer linked to the Experiment Design Tool). Dependent variables are shown at the top of the tree (Node 0; KnowImprove; GraphInter) and they have been rescaled to range between 0 and 1. Indepepdent variables (predictors) are shown at each split: time-on-task working with the Electrical Circuit Lab in seconds (LABTime) and time-on-task working with the Experiment Design Tool in seconds (EDTTime) for knowledge improvement; time-on-task working with the Electrical Circuit Lab in seconds (LABTime) for the graph interpretation skill. The CRT (Classification and Regression Trees) method has been used to grow the tree. The method partitions the data in homogeneous segments with respect to the dependent variable. At each split, the predictor variable is shown together with a statistic, which presents the improvement in the tree from the parent to the child node. At each brannch of

a split (i.e., left and right branch), the tree presents the threshold of the predictor variable, according to which the partitioning of the student sample has taken place. Each node presents mean value (equals to predicted) and standard deviation of the dependent variable, number of students (n) and their precentage in the student sample. Total variance explained for A = 77.71% and B = 54.99%.

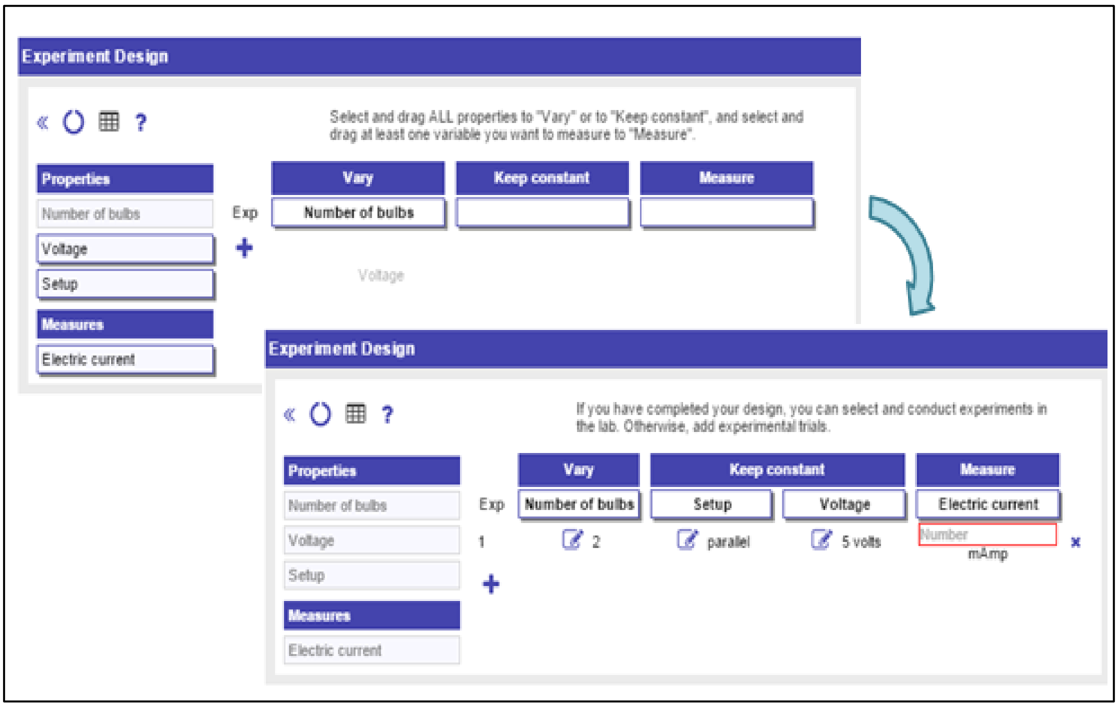


Figure 26

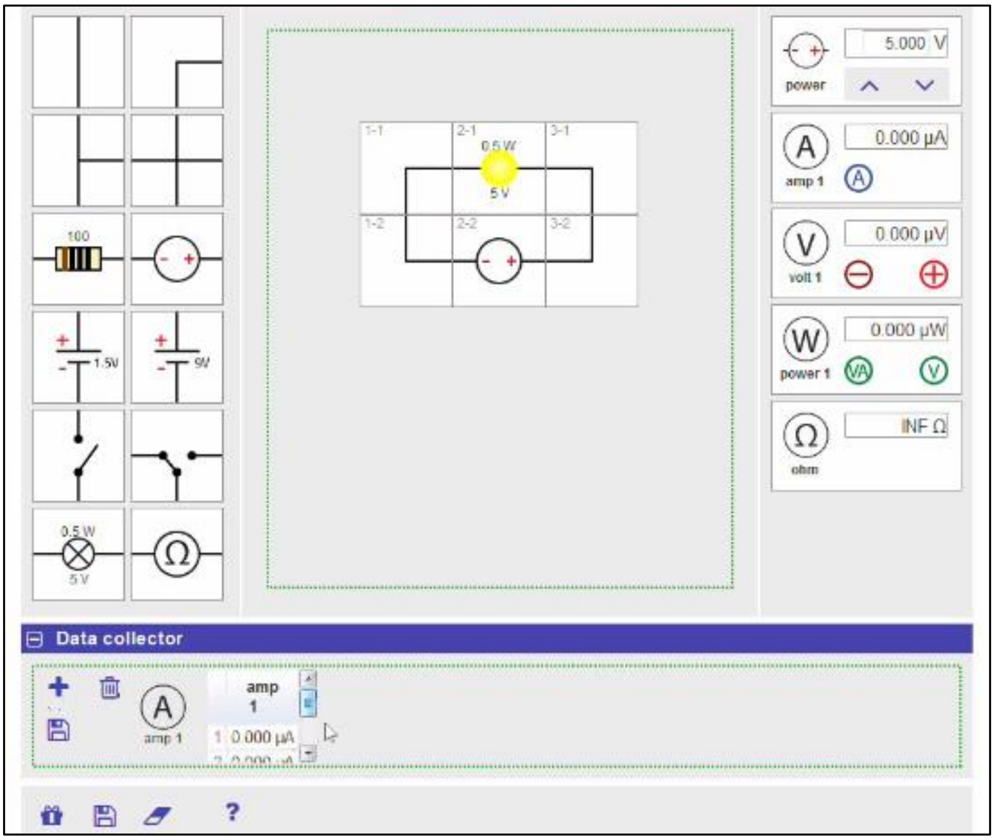

power
5.000 V
amp 1
0.000 µA
volt 1
0.000 µV
power 1
0.000 µW
ohm
INF Ω
Data collector
amp 1
1 0.000 µA

Figure 27

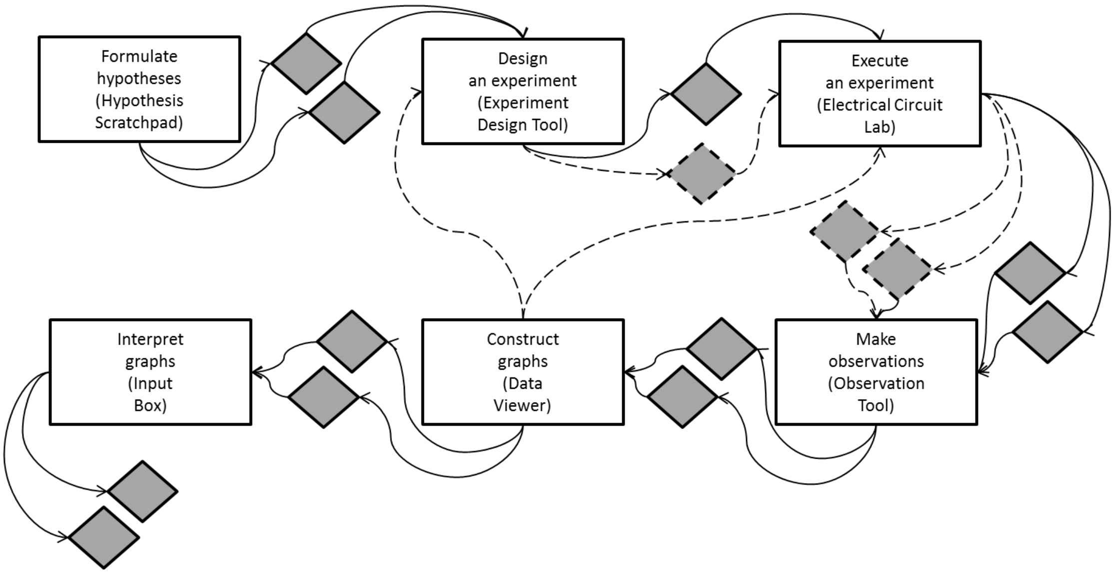


Figure 28

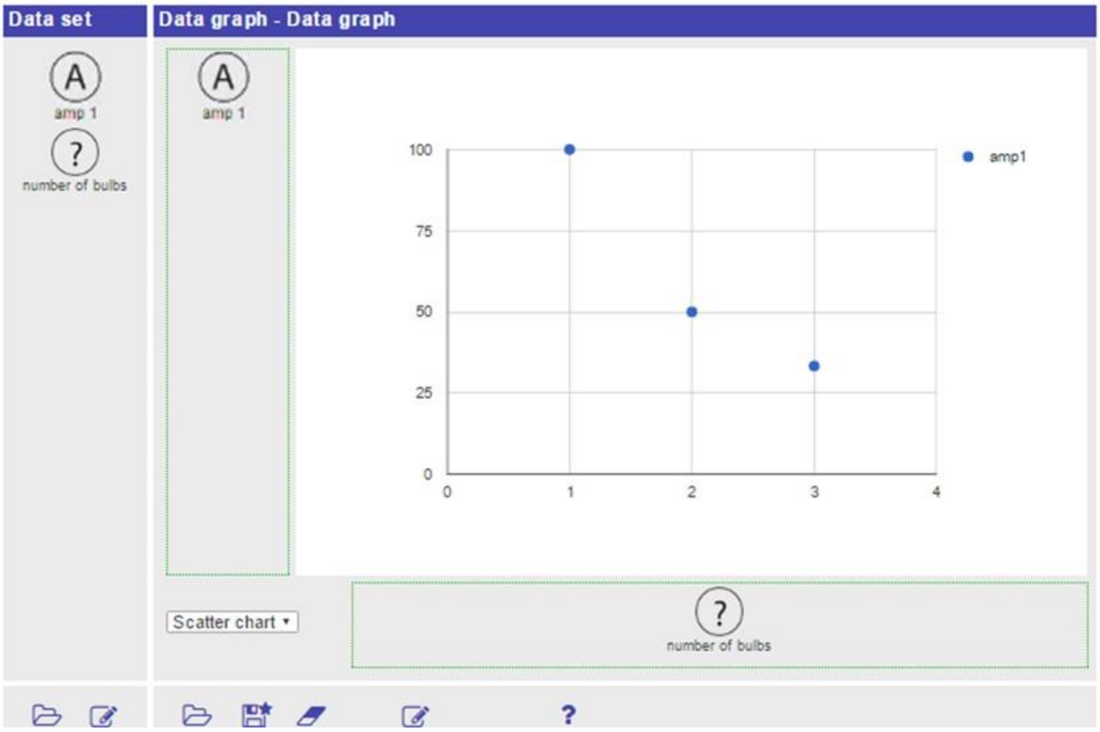


Figure 29

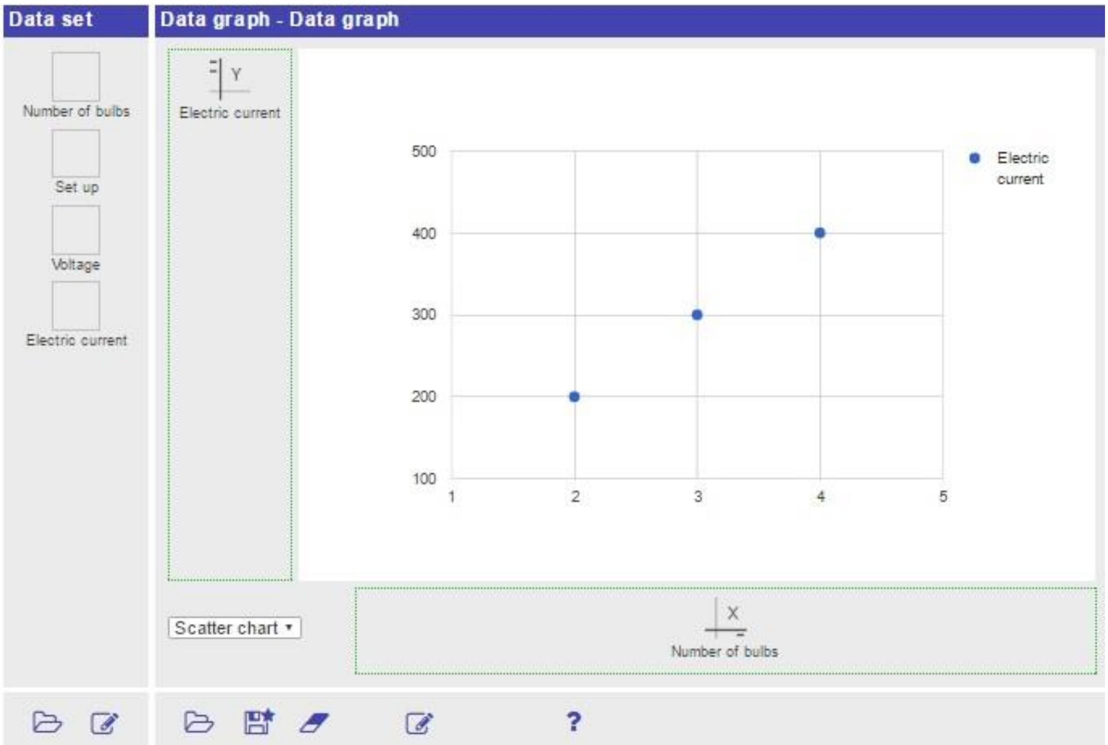

Data set
Number of bulbs
Set up
Voltage
Electric current
Data graph - Data graph
Y
Electric current
500
400
300
200
100
1
2
3
4
5
Electric current
Scatter chart
X
Number of bulbs
?

Figure 30

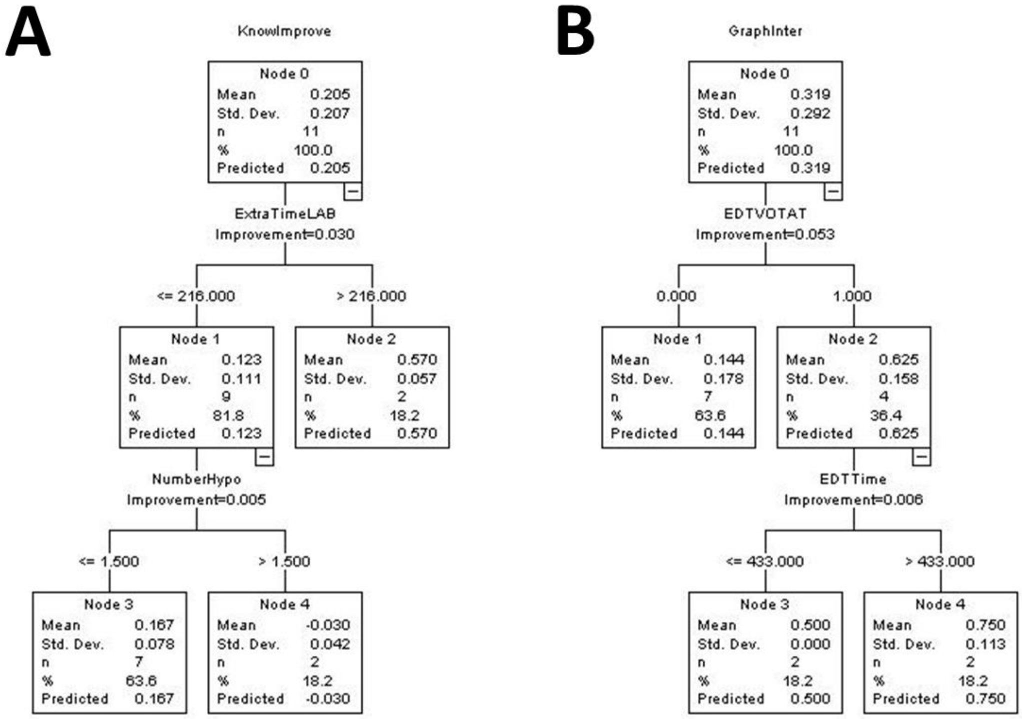

A
KnowImprove
Node 0
Mean 0.205
Std. Dev. 0.207
n 11
% 100.0
Predicted 0.205
ExtraTimeLAB
Improvement=0.030
<= 216.000
> 216.000
Node 1
Mean 0.123
Std. Dev. 0.111
n 9
% 81.8
Predicted 0.123
Node 2
Mean 0.570
Std. Dev. 0.057
n 2
% 18.2
Predicted 0.570
NumberHypo
Improvement=0.005
<= 1.500
> 1.500
Node 3
Mean 0.167
Std. Dev. 0.078
n 7
% 63.6
Predicted 0.167
Node 4
Mean -0.030
Std. Dev. 0.042
n 2
% 18.2
Predicted -0.030
B
GraphInter
Node 0
Mean 0.319
Std. Dev. 0.292
n 11
% 100.0
Predicted 0.319
EDTVOTAT
Improvement=0.053
0.000
1.000
Node 1
Mean 0.144
Std. Dev. 0.178
n 7
% 63.6
Predicted 0.144
Node 2
Mean 0.625
Std. Dev. 0.158
n 4
% 36.4
Predicted 0.625
EDTTime
Improvement=0.006
<= 433.000
> 433.000
Node 3
Mean 0.500
Std. Dev. 0.000
n 2
% 18.2
Predicted 0.500
Node 4
Mean 0.750
Std. Dev. 0.113
n 2
% 18.2
Predicted 0.750

Figure 31

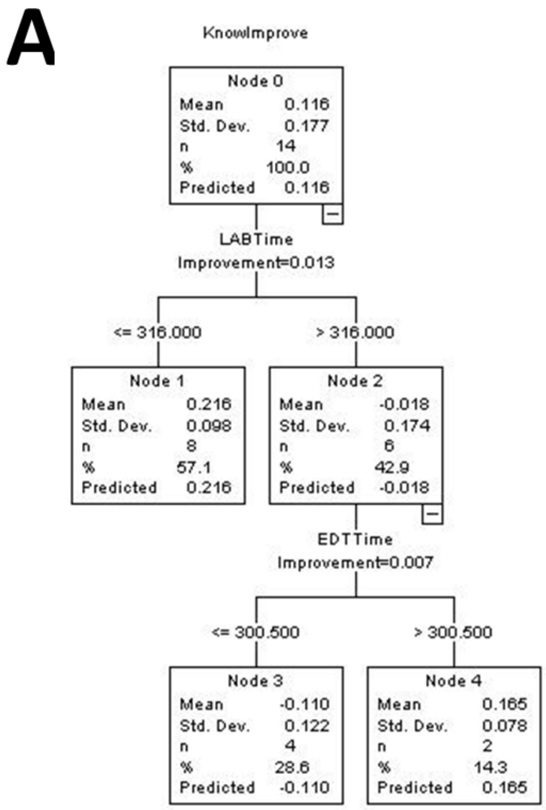

A
KnowImprove
Node 0
Mean 0.116
Std. Dev. 0.177
n 14
% 100.0
Predicted 0.116
LABTime
Improvement=0.013
<= 316.000
> 316.000
Node 1
Mean 0.216
Std. Dev. 0.098
n 8
% 57.1
Predicted 0.216
Node 2
Mean -0.018
Std. Dev. 0.174
n 6
% 42.9
Predicted -0.018
EDTTime
Improvement=0.007
<= 300.500
> 300.500
Node 3
Mean -0.110
Std. Dev. 0.122
n 4
% 28.6
Predicted -0.110
Node 4
Mean 0.165
Std. Dev. 0.078
n 2
% 14.3
Predicted 0.165
B
GraphInter
Node 0
Mean 0.166
Std. Dev. 0.216
n 14
% 100.0
Predicted 0.166
LABTime
Improvement=0.022
<= 239.000
> 239.000
Node 1
Mean 0.366
Std. Dev. 0.217
n 5
% 35.7
Predicted 0.366
Node 2
Mean 0.056
Std. Dev. 0.117
n 9
% 64.3
Predicted 0.056

Figure 32

Table 18. Differences between conditions in time-on-task and student behaviour during retrospective action.

	Students in the first condition (Data Viewer linked to the Electrical Circuit Lab)	Students in the second condition (Data Viewer linked to the Experiment Design Tool)	istic
Time-on-task working with the Experiment Design Tool in seconds (EDTTime)	292.45 (standard deviation = 166.01)	197.07 (standard deviation = 130.95)	Mann-Whitney Z = -1.59^{ns}
Percentage of students who returned to the Experiment Design Tool (ReturnEDT)	45.5	92.9	Chi Square = 7.23**; Phi = 0.52**
Average extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT)	26.73 (standard deviation = 44.30)	133.71 (standard deviation = 121.90)	Mann-Whitney Z = -2.82**
Time-on-task working with the Electrical Circuit Lab in seconds (LABTime)	562.27 (standard deviation = 318.06)	352.07 (standard deviation = 222.09)	Mann-Whitney Z = -1.75^{ns}
Percentage of students who returned to the Electrical Circuit Lab (ReturnLAB);	36.4	64.3	Chi Square = 1.95^{ns}; Phi = 0.28^{ns}
Average extra time spent on the Electrical Circuit Lab in seconds (ExtraTimeLAB)	110.18 (standard deviation = 235.92)	122.21 (standard deviation = 131.24)	Mann-Whitney Z = -1.16^{ns}
Average total time spent during retrospective action (TotalTimeReturn)	157.82 (standard deviation = 306.84)	292.07 (standard deviation = 277.90)	Mann-Whitney Z = -2.04*
*Note: Likelihood ratio chi-square values are displayed; ns = non-significant; * p <0.05; ** p < 0.01.*			

Table 19: Correlations among parameters of retrospective action in the first condition (Data Viewer linked to the Electrical Circuit Lab).

	Time-on-task working with the Electrical Circuit Lab in seconds (LABTime)	Extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT)	Extra time spent on the Electrical Circuit Lab in seconds (ExtraTimeLAB)
Time-on-ask working with the Experiment Design Tool in seconds (EDTTime)	0.36^{ns}	-0.58^{ns}	-0.46^{ns}
Time-on-task working with the Electrical Circuit Lab in seconds (LABTime)		-0.75^{**}	-0.62^{*}
Extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT)			0.56^{ns}

Note: Spearman's rho correlation coefficients are displayed; ns = non-significant; * p <0.05; ** p < 0.01.

Table 20. Correlations among parameters of retrospective action in the second condition (Data Viewer linked to the Experiment Design Tool).

	Time-on-task working with the Electrical Circuit Lab in seconds (LABTime)	Extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT)	Extra time spent on the Electrical Circuit Lab in seconds (ExtraTimeLAB)
Time-on-ask working with the Experiment Design Tool in seconds (EDTTime)	0.41^{ns}	-0.64^{*}	-0.26^{ns}
Time-on-task working with the Electrical Circuit Lab in seconds (LABTime)		-0.49^{ns}	-0.25^{ns}
Extra time spent on the Experiment Design Tool in seconds (ExtraTimeEDT)			0.79^{**}

Note: Spearman's rho correlation coefficients shown; ns = non-significant; * p <0.05; ** p < 0.01.

2 Teachers' evaluation

2.1 Data Sample

2.1.1 Pre-questionnaire evaluation data

A total of 231 questionnaires has been collected between December 2015 and July 2016. After cleaning the data and removing duplications [1] the number of questionnaires came down to 150. This number corresponds to unique teachers. Apart from the project related countries teachers from additionally 10 countries have also contributed to the surveys.

Since Phase B, necessary actions have been taken to address a low involvement rate in Switzerland and the Netherlands and a small increase can be seen, both in registered Pilot teachers and number of pre-questionnaires with one responses for Switzerland and two for the Netherlands.

After matching the pre data with the post received data, a total of 117 responses have been taken into account for the analysis and comparison with the post data in 2.1.2.

While overall a significant amount of data was collected, the amount per country is limited, and therefore no country analysis will be done. In this way, we can avoid wrong assumptions that can lead to inaccurate generalisations and conclusions.

[1] In the case of duplications, the oldest dated and most complete questionnaire has been kept while the most recent one has been removed and not taken into account for this analysis.

How do teachers intend to use Go-Lab?

In Figure 33 we see teachers' replies regarding how they intend to use Go-Lab. As we can see, the majority of teachers (43%) came to Pilot Phase C with the intention to create their own ILSs which is a clear indication of their experience and previous involvement to the project. 37% of the teachers were interested in using the repository and finding appropriate online laboratories while the smallest percentage, 21%, was interested in reusing already existing ILSs. It becomes very clear then that the 1% rule in Internet, which states that 90% of the participants of a community only view content, 9% of the participants edit content, and 1% of the participants actively create new content[1], does not really apply to Go-Lab anymore. In the Go-Lab case, participating teachers appear to be more active than usual and it is safe to conclude that their previous experience in using the platform results in them taking the role of content developer instead that of the consumer.

1 See http://en.wikipedia.org/wiki/1%25_rule_%28Internet_culture%29

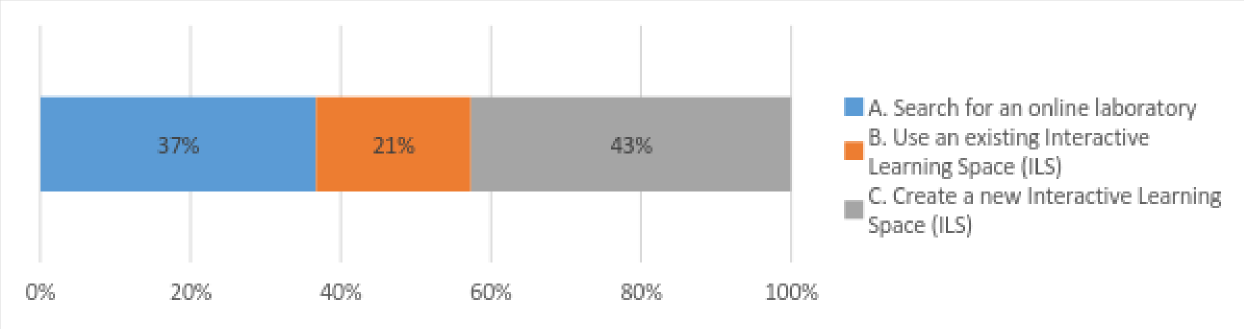


Figure 33. How do teachers intend to use Go-Lab.

How experienced are teachers regarding their science teaching?

Figure 34 provides us information on Go-Lab teachers' experience regarding their science teaching. Teachers were asked to state whether they agreed or not with a variety of statements targeting the adequacy of their science knowledge in relation to the subjects they teach, their experience in designing lesson plans that include technology, their ICT knowledge, their capacity to choose and adapt the technologies that fit better to their pedagogical needs, their student assessment methods and finally the use of different teaching methods.

In Figure 34 we can see that the majority of Go-Lab teachers, 86%, were confident that they have sufficient knowledge about science (i.e. Biology, Physics etc.) which allows them to teach their science classes. This understanding teachers have is usually a working understanding of the issues involved but are rarely, as we can see in the interviews below, explicit (Samarapungavan, 1992).Their ability to assess students' performance along with their capacity to choose the appropriate technology to enhance their science classes score also quite high on their level of experience (Figure 34, 4.3 & 4.8).

When it comes to how Go-Lab teachers felt regarding the training they have received to use different technologies for learning science, 56% believe that it is adequate (Figure 34, 4.6). Consequently, a 44% feels that more training is needed in order to get them up to speed with the newest technologies. A similar percentage of Go-Lab teachers feels that they are not experienced enough when it comes to the creation of science lessons so it is safe to assume that the satisfaction of these two needs is strongly related to teachers' interest in Go-Lab (Figure 34, 4.9).

Overall and after taking into account teachers' responses regarding their experience in using ICT during science teaching, their capacity to create lesson plans and their ability to choose appropriate teaching approaches, we can conclude that similar to what we have observed in Pilot phase B, the profile of the Go-Lab teacher who has participated in the evaluation process is pedagogically experienced but with room of improvement in relation to technical skills and the knowledge of new technologies.

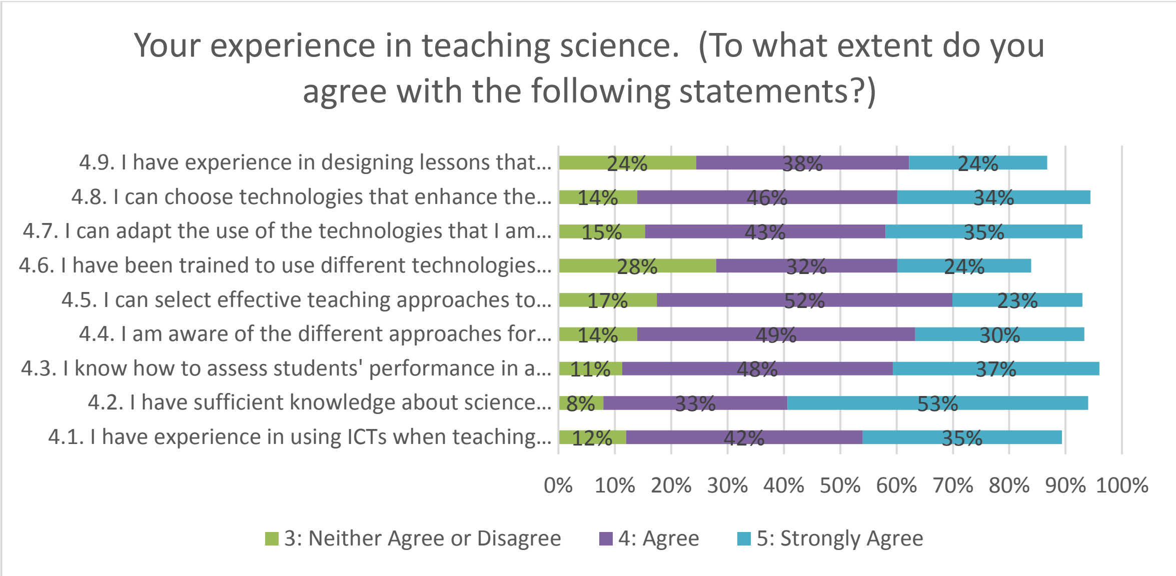


Figure 34. How experienced are teachers regarding their science teaching.

How do teachers rate their technological skills

In Figure 35 we can see how teachers have rated their knowledge and familiarity regarding the selected technological skills.

71% of teachers were very familiar with the use of online laboratories and simulations while they were also confident in passing this knowledge to others. This result matches findings from 2013 according to which 70% of teachers around Europe have at least 5 years of ICT experience (Wastiau, Blamire, Kearney, Quittre, Van de Gaer & Monseur 2013). A slightly higher percentage of 77% has also being using online repositories and educational material widely. Lastly, only 27% of the teachers knew how to use authoring tools i.e., Adobe Dreamweaver, Coffeecup etc.

Combining these results with the Go-Lab use indications we have seen in Figure 33 we can come to a number of conclusions:

- Go-Lab teachers seemed to be particularly familiar with the use of online repositories and educational resources which made them automatically much more responsive when it comes to the use of Go-Lab repository as a source of discovering online laboratories and related educational material.
- Only a small group of teachers (27%) was familiar with the use of authoring tools. Consequently, only 24% of teachers appeared to be interested in using the Go-Lab authoring tool and develop their own ILSs.
- 11% of teachers feel confident enough to teach the use of authoring tools to others so we can see that from this quite experienced group, we have an emerging super group which has the capacity to pass their knowledge to others.

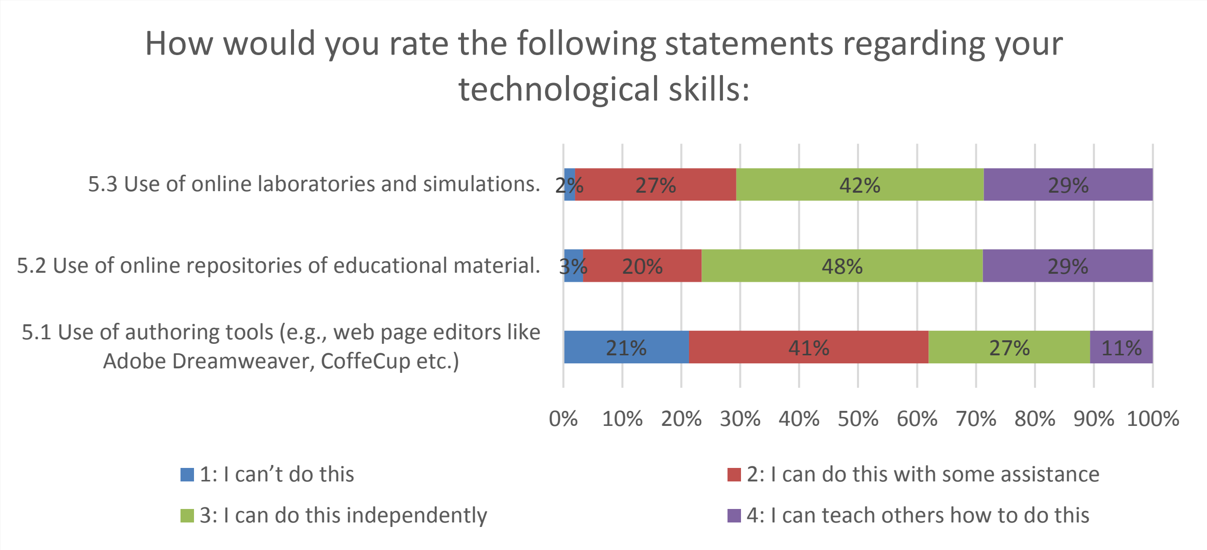


Figure 35. How do teachers rate their technological skills.

How do teachers understand IBSE scenarios

Figure 36 presents how Go-Lab teachers have understood and rated a selection of teaching scenarios in relation to how they promote and develop students' IBSE skills.

The scenario that includes the analysis of laboratory collected data, the generation of conclusions and the final presentation of these conclusions to the targeted audience, has been selected by 89% of the teachers as the most representative in relation to IBSE. A few explanatory quotes that reveal teachers' views and understanding can be found below:

- "When students make presentation of what they discovered and the data they collected they are in fact teaching others. When they teach others what they have learned, it helps them to understand the concepts even more. Students get a chance to show off their learning.", Croatian teacher
- "Every student needs to be able to present their work to other students and to their teacher. If there is no misconception in their heads about some science principles, or exercise that they completed, then they wouldn't have any problem present their findings to others.", Hungarian teacher
- "One of the best things in doing different measurements is the possibility to analyse the data, which you've collected. Students should know how to do that and why it is so important. Thanks to data analysis one is able to understand the main problem of an experiment, which he has been working on.", Polish teacher

The scenarios of "Having students use graphics on the Internet to explain how gas molecules move" and *"A class discussion about the arrangement of the periodic table"* are also perceived as good opportunities for developing IBSE skills.

A small but significant group of teachers (31%) do not seem to be convinced regarding the IBSE value of having students follow a procedure to complete a lab activity of experimentation. According to a Polish teacher *"Such graphics could be helpful to present difficult topics but they are just a given thing, students just watch them, instead of e.g. creating them by themselves."* What is interesting in this scenario is that although it is not an obvious IBSE scenario, 69% of the teachers declare that with the right guidance and input from the teacher, the implementation of the specific procedure can be converted into an IBSE activity.

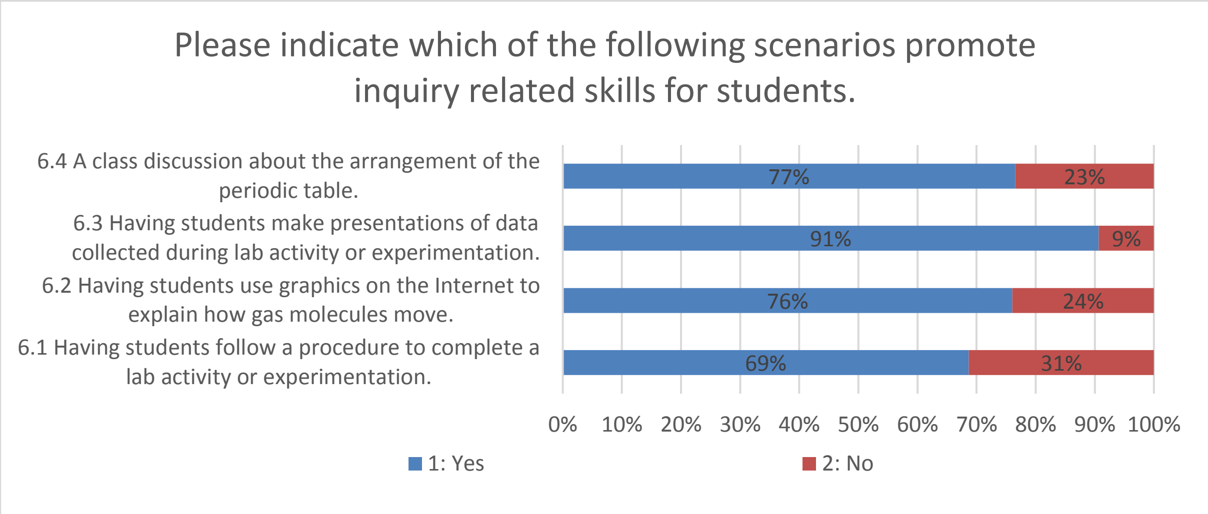


Figure 36. How do teachers understand IBSE scenarios.

Figure 37 shows Go-Lab teachers' agreement/disagreement to a selection of statements related to the implementation of inquiry based science.

In this same figure we can see clearly that 83% of the teachers are committed to continually find better ways to teach inquiry based science which in combination to their interest in using online laboratories and finding educational material as we have seen earlier, form the basis of their involvement and interest in the project. 72% (in comparison to 65% in Pilot phase B) of the teachers believe that they know how to explain students to conduct inquiry based science while only 1% feel (5% in Pilot phase B) that despite their efforts they will never be able to conduct inquiry based activities as good as other approaches.

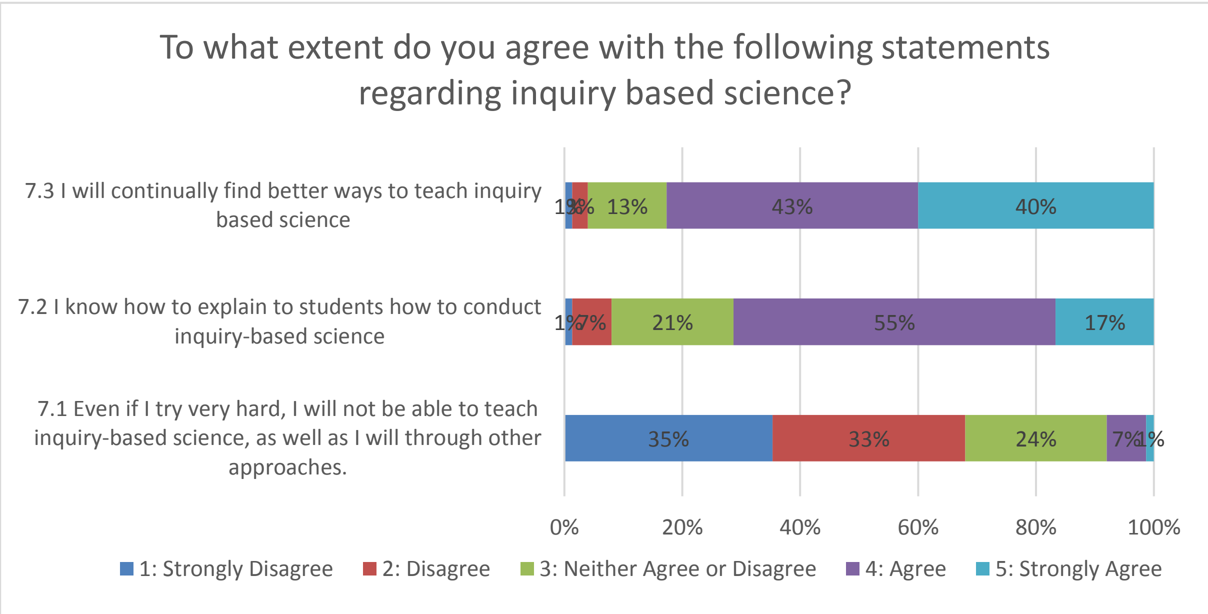


Figure 37. Teachers' views on inquiry-based science.

How often to teachers intend to use specific parts of Go-Lab

Figure 38 provides us with information regarding how frequently Go-Lab teachers intended to use the basic three components of Go-Lab (authoring facility, repository, ILSs).

More than 60% of the Go-Lab teachers expressed their intention to use ILSs on a daily/weekly/monthly basis, with 61% planning to do the same with the Go-Lab repository. What is really interesting though and very different from what we have seen in Pilot phase B is that 43% of the teachers are into using the authoring facilities in a monthly/daily basis. This fact alone signals that the teachers who have responded to our questionnaires are not new but Go-Lab teachers who are revisiting the system with a more complete understanding of its capacities and they are more confident in going from the consumer to the content developer role.

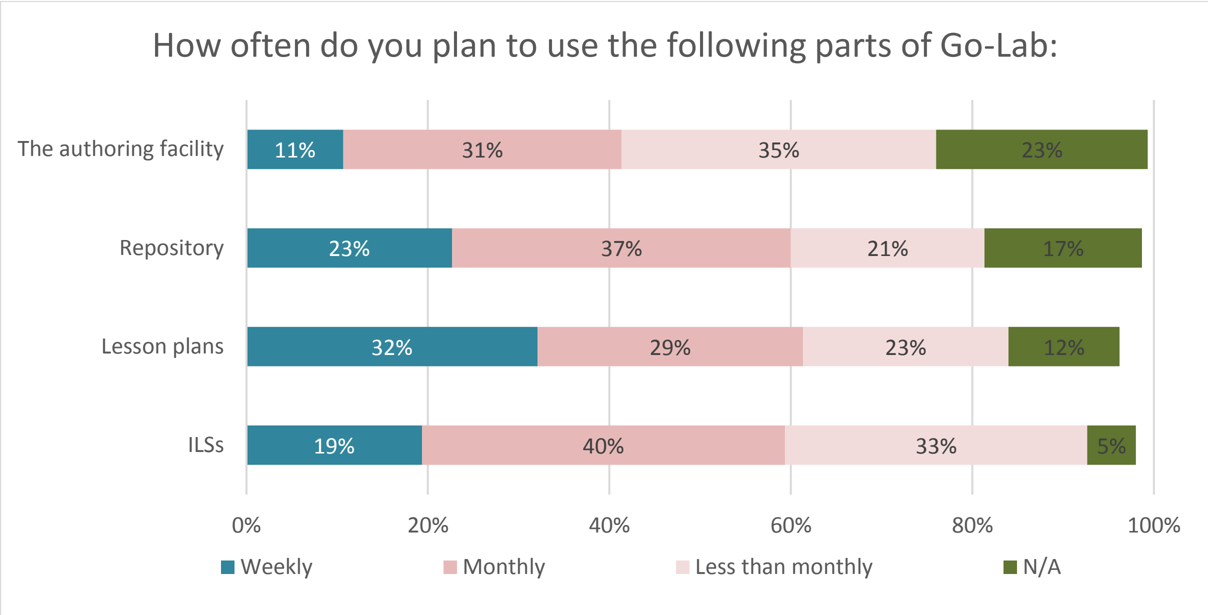


Figure 38. Frequency of use for Go-Lab parts.

2.1.2 Post-questionnaire evaluation data

A total of 143 post questionnaires has been collected between December 2015 and July 2016. After cleaning the data, removing duplications and incomplete entries and finally matching post with pre data the number of questionnaires came down to 117.

This number corresponds to unique teachers with multiple implementations (i.e. a teacher may be counted multiple times as a result of multiple implementations) but as explained at the beginning, in section 11.3 we are analysing and comparing pre & post data which has been received by the same teachers. As a result and after matching teachers' codes, we arrived at a total of 95 teachers who have responded to both pre and post questionnaires.

How have teachers used Go-Lab?

Figure 39. How have teachers used Go-Lab shows that 38% of the teachers have created their own ILS while 33% of the teachers have used an existing ILS. 30% have used Golabz only for finding an online laboratory.

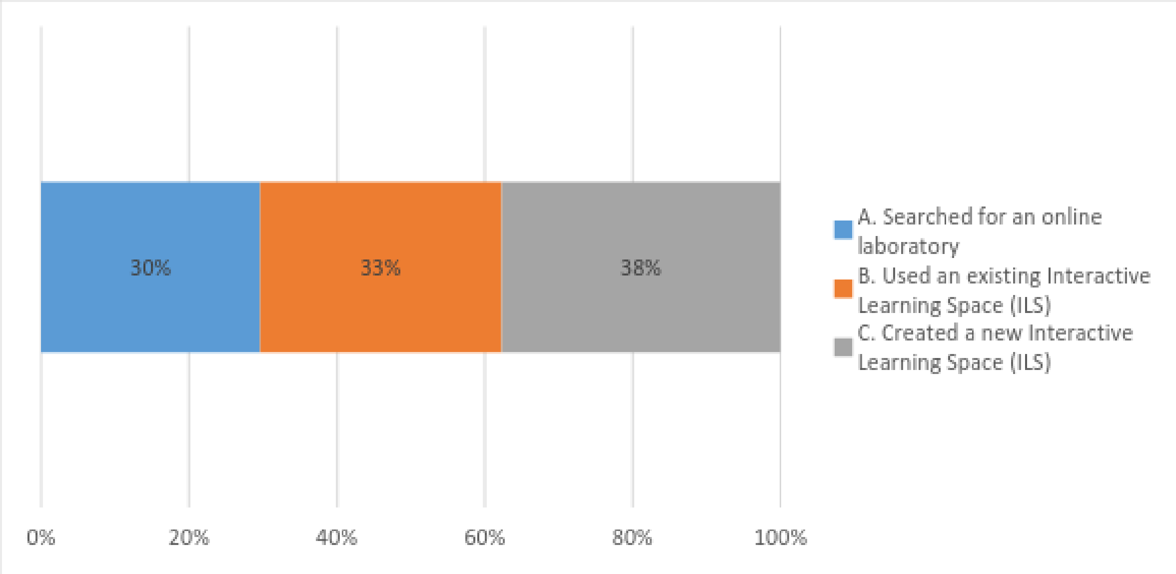


Figure 39. How have teachers used Go-Lab.

A comparison between Figure 39 and Figure 33 reveals that when it comes to the use of Go-Lab, teachers came close to achieving their own expectations. In Figure 1, 37% of the teachers were planning to use Golabz for finding online laboratories with 43% declaring their intention to create their own ILS. Figure 7 shows that less teachers have finally searched for online laboratories with an increasing number of teachers, 33%, using existing ILSs. As a result, 38% of teachers have created their own ILS. The increased use of existing ILSs is a natural outcome of the intensive ILS creation that took place during Pilot Phase B. With more than 350 ILSs currently available and thanks to the localisation efforts that took place throughout the last year, a 5% of the teachers who intended to create their own ILSs have actually found what they were looking for in the existing collection of ILSs.

Science teaching experience

- How experienced are teachers regarding their science teaching (before) vs How experienced are teachers regarding their science teaching (after)

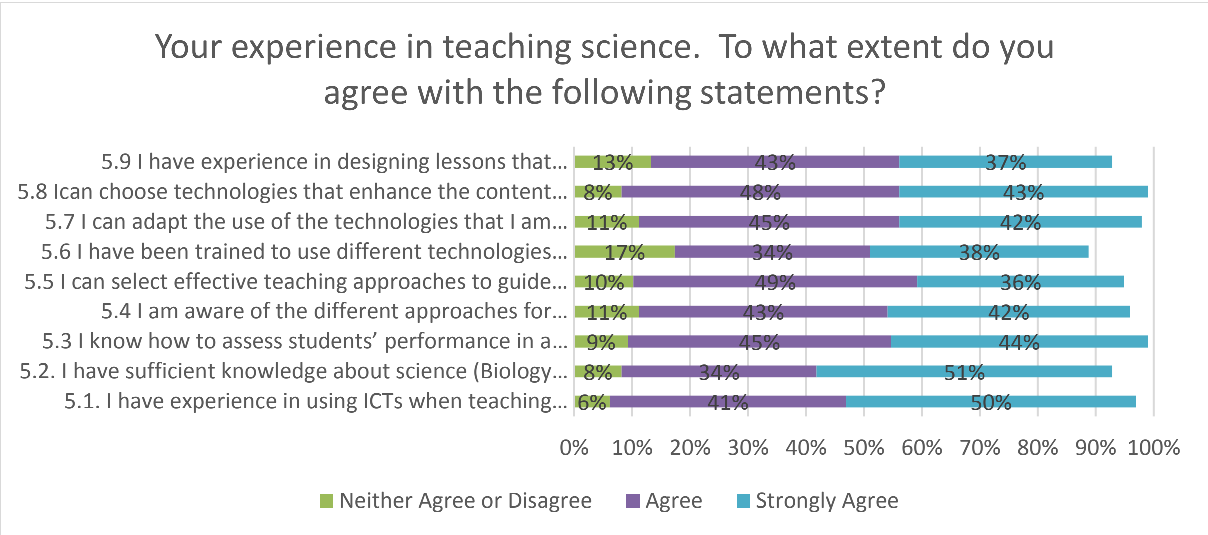


Figure 40. Teachers' experience in teaching science.

Comparing the above Figure 40 with Figure 34 we can see that due to our teachers' experienced profile, the use of Go-Lab helps teachers maintain their teaching skills with an interesting increase of 5% related to the assessment of students' performance in a classroom which can be attributed to the further improvement of the related apps.

- How do teachers rate their technological skills (before) vs How do teachers rate their technological skills (after)

Teachers' answers regarding their experience in the use of different Go-Lab tools can be seen in Figure 41. According to it, more than 87% of the responders feel confident when it comes to the use of online laboratories and educational repositories. Teachers feel also strongly that they are in a position to not only use these tools independently but to also teach their use to others. In the use of authoring tools, we also have 89% being in the position to use the tools and even explain their use to other colleagues.

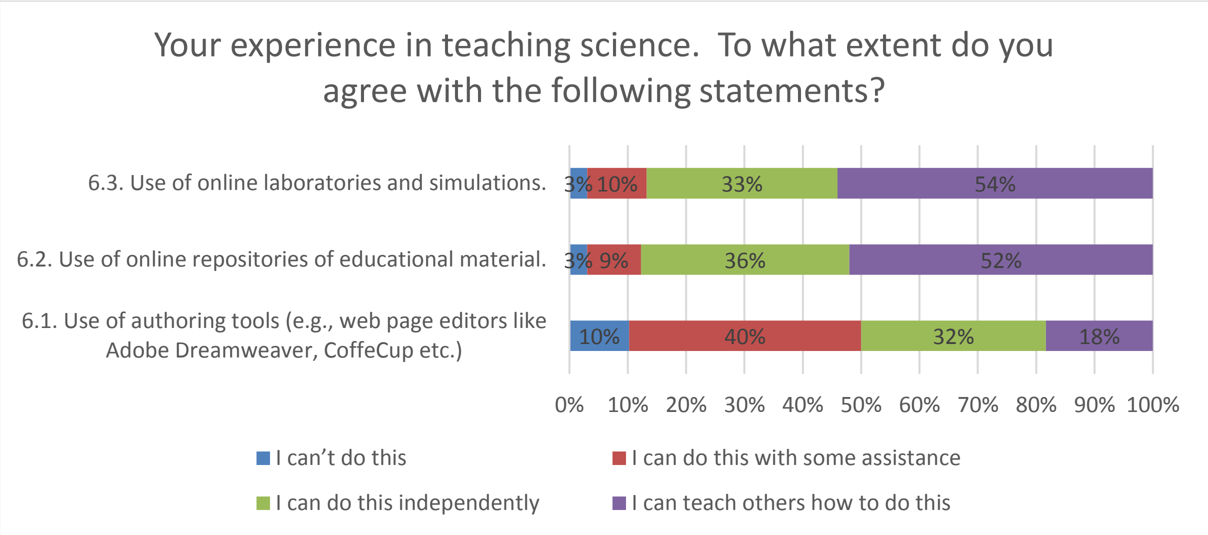


Figure 41. Teachers' technological skills.

Looking back to teachers' pre answers, Figure 35, and after their exposure to the Go-Lab tools, we can see an increase in the percentage of teachers that feel capable of using online laboratories and the repository independently. In the use of authoring tools there is also a noticeable increase of 5% in the number of teachers that feel confident to use on their own.

- How do teachers understand IBSE scenarios (before) vs How do teachers understand IBSE scenarios (after)

In this question, teachers have been presented with 4 hypothetical class scenarios that they were invited to decide whether they promote the development of student inquiry skills or not. As one can see from teacher's answers, all suggested scenarios can be used as opportunities to teach inquiry skills to students. The class discussion and having students following a procedure to complete a lab activity or experimentation are the ones collecting most criticism though with more than 30% of teachers rejecting their contribution to the acquisition of inquiry related skills.

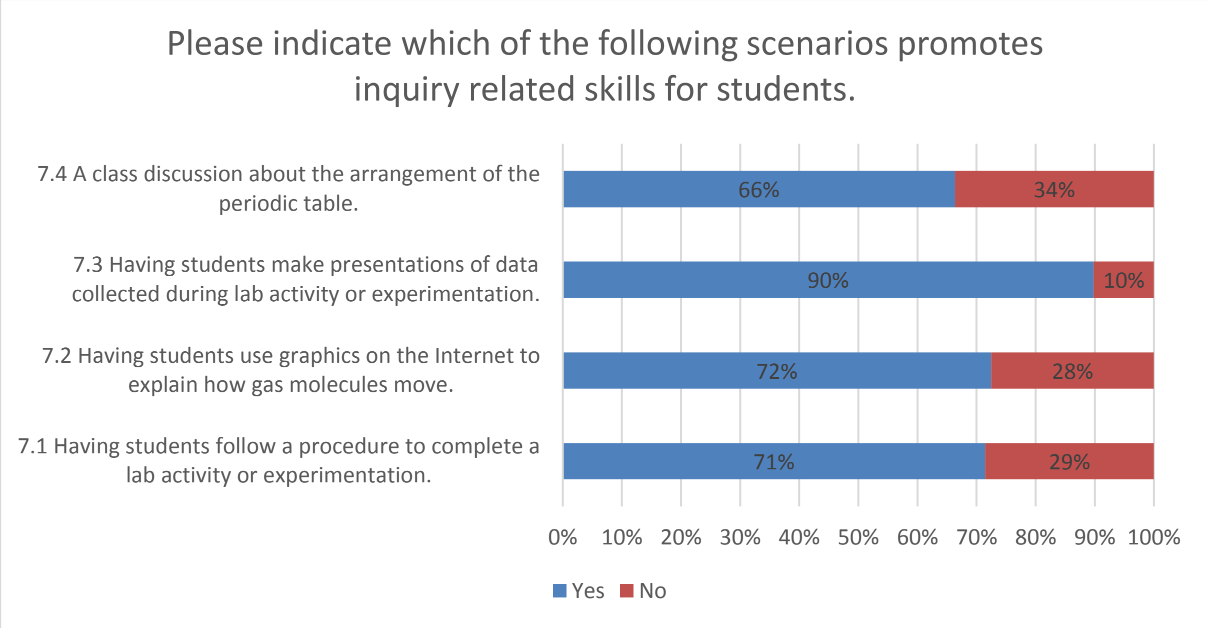


Figure 42. Understanding on inquiry based scenarios.

A comparison between Figure 36 and Figure 42, which describes teachers understanding of IBSE scenarios before and after teachers used Go-Lab, shows that for all 4 scenarios, teachers' views have slightly changed after the use of Go-Lab. For all scenarios the change of opinion is between 1% and 4%. Some quote that provide an insight on teachers' perceptions, can be found below More explanations about this can be found it teachers' quotes below:

- "It is not enough that students follow a procedure to complete a lab activity or experimentation. In the Investigation phase, with teacher's help, the students must design the experiments – but no if the answers are known.", Romanian teacher
- "Students follow a predefined set of steps. This procedure it is not the outcome of their own since they haven't been through the usual investigation phase during this process." , Greek teacher

Teachers' views on inquiry based science

Figure 11 shows how teachers feel regarding their own inquiry based skills. As we can see, 84% state that after using Go-Lab they are committed to continue finding better ways to teach inquiry based science with 79% feeling confident enough to explain to their students how to conduct inquiry based science. As a result, 77% of the responders believe that they are in a position to teach inquiry-based science, as well as they can do with other educational approaches.

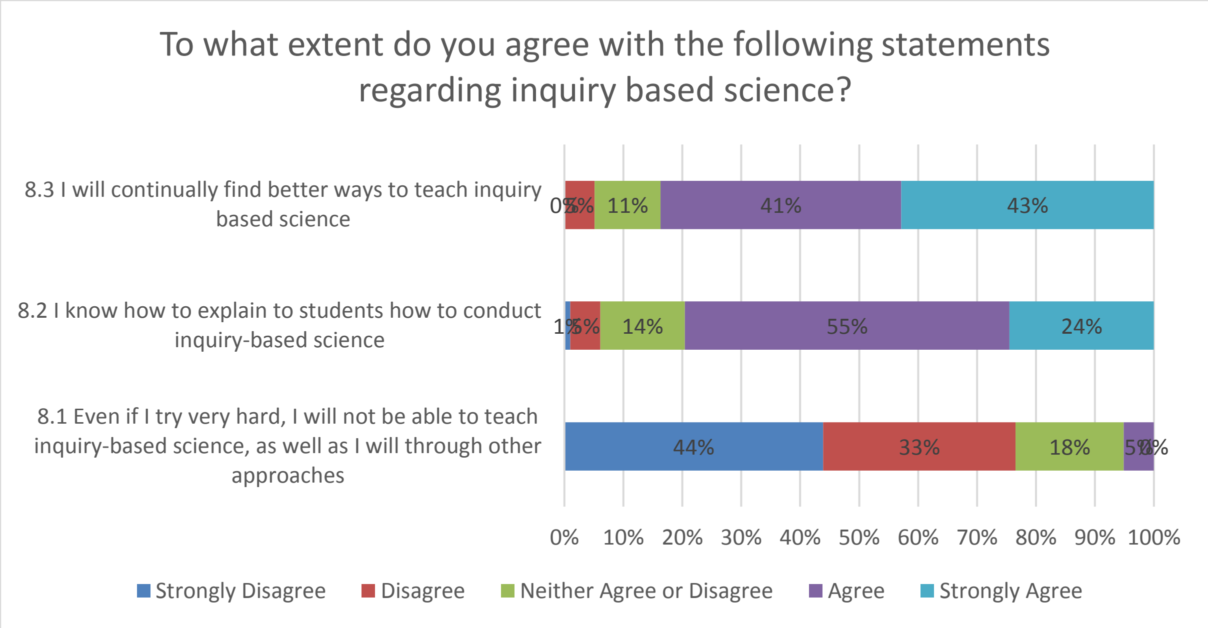


Figure 43.Teachers' views on inquiry based science.

- How often do teachers intend to use specific parts of Go-Lab vs How often do teachers use specific parts of Go-Lab

In Figure 43 we can see how often teachers use the different parts of Go-Lab. The online labs repository seems to be the most popular with 41% of teachers using it on monthly basis. Existing ILSs are also popular with 27% of the responders using them monthly. When it comes to the authoring facility 54% state that they tend to use it less than monthly while 46% of the teachers have been using the authoring tools on monthly/weekly basis. A small, but still significant, percentage of 20% of teachers are using all parts on a weekly basis.

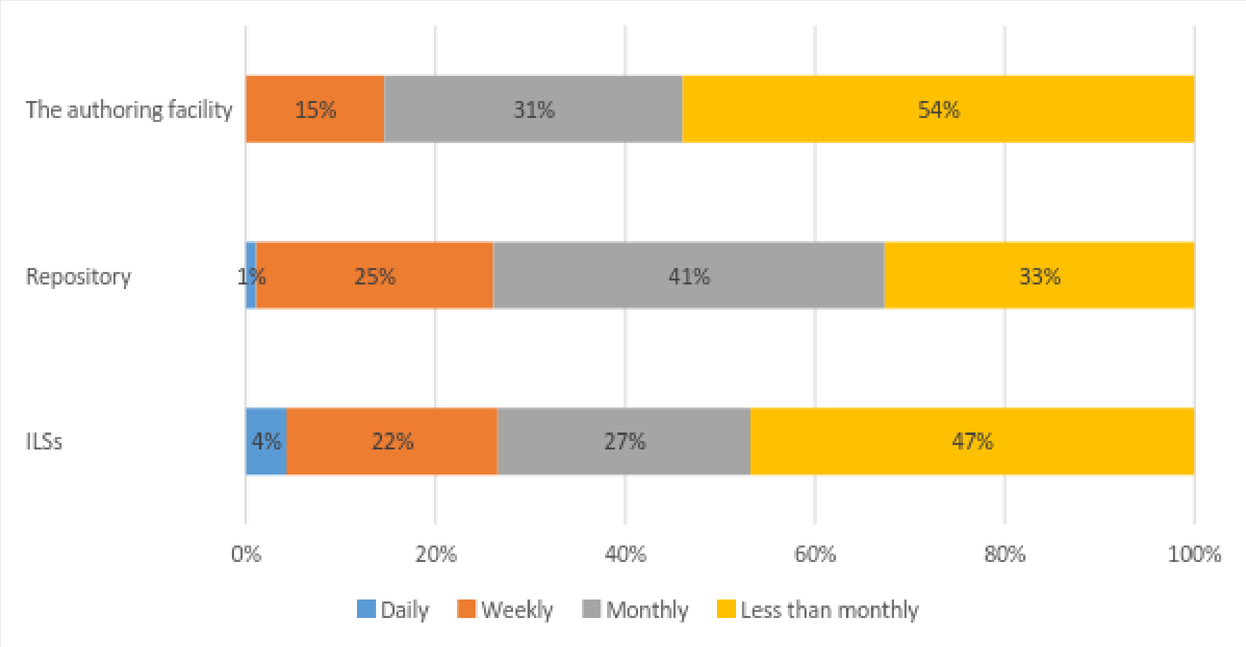


Figure 44. Frequency of teachers' use of Go-Lab.

Comparing the above recorded frequencies, Figure 44, with teachers' intentions, as they can be seen in Figure 33, behaviours appear to be quite consistent. 11-25% of teachers intended to use the various Go-Lab parts on weekly basis, which is close the actual case according to Figure 44. The majority of teachers, 30-40%, were planning to use the tools on a less than a month basis which has also been validated with percentages reaching up to 47% in the case of the authoring facility.

Go-Lab use and usability

When it comes to the usability of the different Go-Lab parts 94% of the teachers enjoyed using the Go-Lab portal while 86% found the navigation clear and understandable. 79% of the responders stated that they found the adaptation of existing ILSs easy while 70% could easily create their own ILS. Despite the variations, 91% of the teachers are willing to continue using Go-Lab in the future which shows a strong interest and commitment to further pursue the use of the portal. Figure 45 summarizes the data.

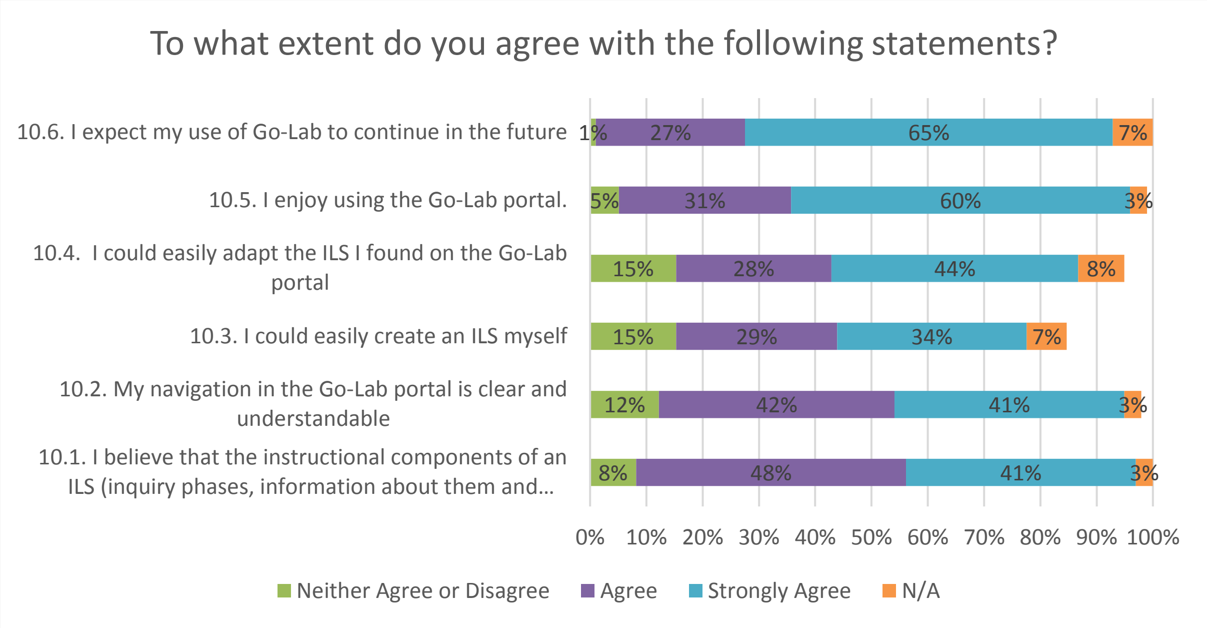


Figure 45. Go-Lab usability.

- Which is the most useful component of the Go-Lab portal for science teachers and why?

In this open ended question, teachers had the opportunity to provide us with information regarding the most useful, based on their experience, component of Go-Lab. As it can be seen in Figure 46. Most of the teachers avoided to provide a clear answer and expressed their satisfaction with all components. From the ones that they clearly expressed their preference the most useful components are:

- Authoring tool
- Repository of ILSs and apps

Some interesting comments and reasoning can be seen below:

- "For me the ILS is the most useful because it offers to teachers who like change and challenges the possibility to create their own learning spaces for their students. Teaching and learning in this sort of environment is a different and rich experience for both teachers and students. the possibility for teachers who have not time or are not used with creating an ILS to find already ILS in different languages and topic dealing with STEM.", French teacher
- "The labs. I made an updated course for my colleagues this year and I dedicated one lesson to explain Go-lab and what it is. Many of them found the Go lab repository really useful, while ILS were a little bit difficult if you didn't have a good digital knowledge.", Italian teacher

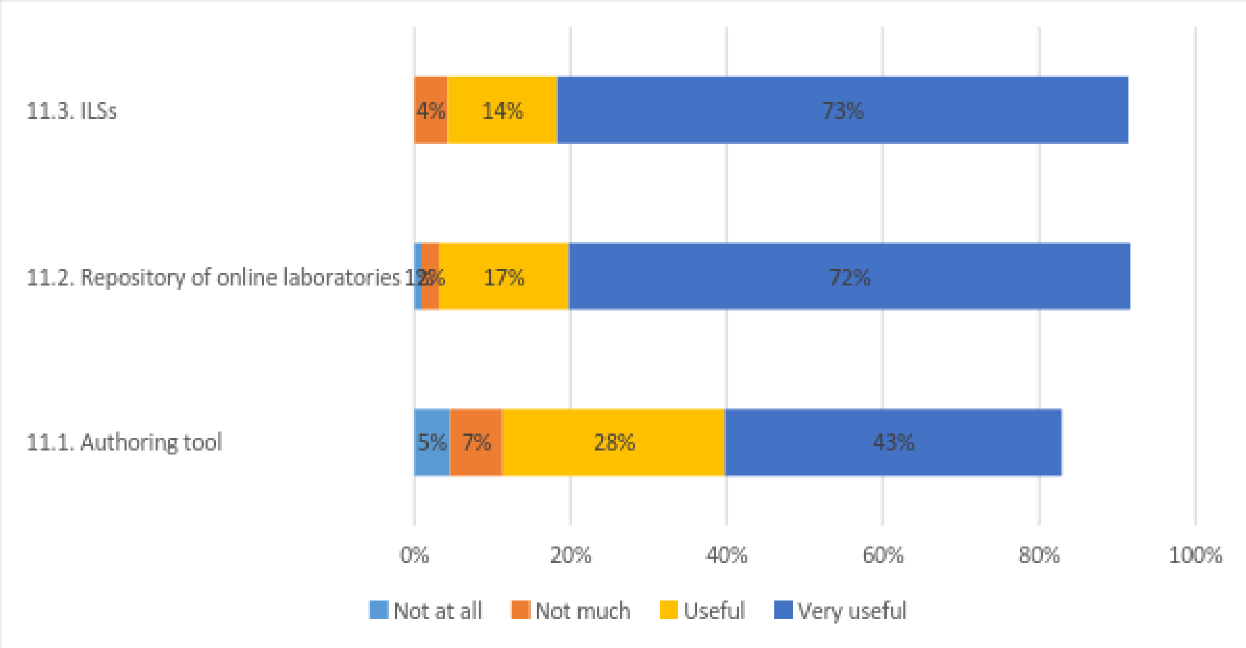


Figure 46. Usefulness of Go-Lab components.

- Which is the least useful component of the Go-Lab portal for science teachers and why?

In this question the majority of teachers agreed that there is no Go-Lab component that it is not useful. Nevertheless, many teachers found in this question the opportunity to share a number of issues that they seem to prevent them from taking full advantage of the Go-Lab tools. The most common of these issues are listed below:

- Need for more primary education focused labs and ILSs
- Need for more Biology related labs

It is worth mentioning at this point, that none of the issues that have been reported in Pilot phase B including technical problems and lack of localization have been mentioned this time, proving that the Go-Lab team has successfully managed to address these problems.

Another interesting remark that is worth mentioning is that according to some teachers the existence of the forum is very important and they are eager to use it but they are looking for more interaction with the laboratory providers who are not very present at the moment.

2.2 Conclusions

The aims of the large-scale evaluation during Pilot phase C were two folded. On one hand we wanted to continue monitoring the impact of the use of Go-Lab tools in teachers' technical skills, IBSE knowledge, use and understanding of online laboratories. On the other hand and taking into account the initial conclusions that have been drawn at the end of Pilot phase B (see D8.3), we wanted to see whether these initial impressions would be validated or not. The conclusions of this section are spread over the previous sections and provide us with some first indications regarding the impact the use of Go-Lab tools has on teachers around Europe.

More specifically:

Teachers' profile: The majority of teachers that participated in the evaluation and are interested in the use of online laboratories have quite developed pedagogical and technological skills. Thanks to the diversity of options that the Go-Lab tools offer, teachers with less experience have the possibility to start discovering the tools by using the repository and identifying labs, apps and existing ILSs that fit their needs.

Knowledge of IBSE: Most of the Go-Lab teachers have a solid knowledge and experience of IBSE. The majority of teachers seem confident in teaching IBSE to their students and to design related activities. What is interesting though is that there is still a significant number of teachers that do not feel confident using IBSE and consider that they still lack skills in order to successfully apply it. Go-Lab is contributing to teachers understanding of IBSE, as a comparison with the D8.3 findings reveals, but continuous support, good practices and training are needed in order support teachers interested in IBSE and help them fully develop their IBSE skills.

Teachers' technical skills: When it comes to their technical skills, teachers are quite confident to use online laboratories and repositories. The use of authoring tools though, is a big challenge for most teachers which also affects their intentions and ways the use the Go-Lab tools. At the end of Pilot phase B we saw a change in teachers' technical skills with a significant rise in the numbers of teachers that were daring to use the authoring tool. The development of the tutoring platform, the various supportive materials that were made available in the course of the previous years and the training sessions that took place all around Europe, have definitely played their role and contributed to this change. At the end of Pilot phase C though we see that the number of ILS creators remains pretty much the same, while the number of ILS consumers has risen. The growth of the ILS repository that took place during the last year of the project is a direct consequence of the development of teachers' technical skills which led to the development of a large number of ILSs covering a variety of topics and languages. Despite the above and as stated in the ICT in education survey, support is still needed in order to encourage teachers with less advanced skills to grow and develop. Despite having access and positive attitudes towards implementing ICT in teaching and learning, teachers often find this difficult and require support – not only technical but also pedagogical (i.e., IBSE). Increasing the training provided by school staff and others to teachers of all disciplines should therefore be encouraged, including subject specific training on learning applications. (Wastiau, et al. 2013).

Use of authoring tools: The use of Go-Lab helped teachers to gain familiarity with the basic principles of authoring tools that they can use in producing their own ILS. As a result we can see that the shift in attitudes regarding the use of Go-Lab that started in Pilot phase B continues in Pilot phase C. Teachers that wish to create ILSs have the capacity to do so, while the outputs of the ILS creation also strengthened the group of ILS consumers.

Need of training and support: The introduction of new tools in combination with IBSE, require training and support in order to provide teachers with the necessary background and skills.

Finally, regarding the response rate, additional actions need to be taken it order to motivate teachers to fully participate in the validation process. Incentives, rewards, connection to certification are just some of the suggestions and possible solutions that will be considered.

3 Students' evaluation (large scale)

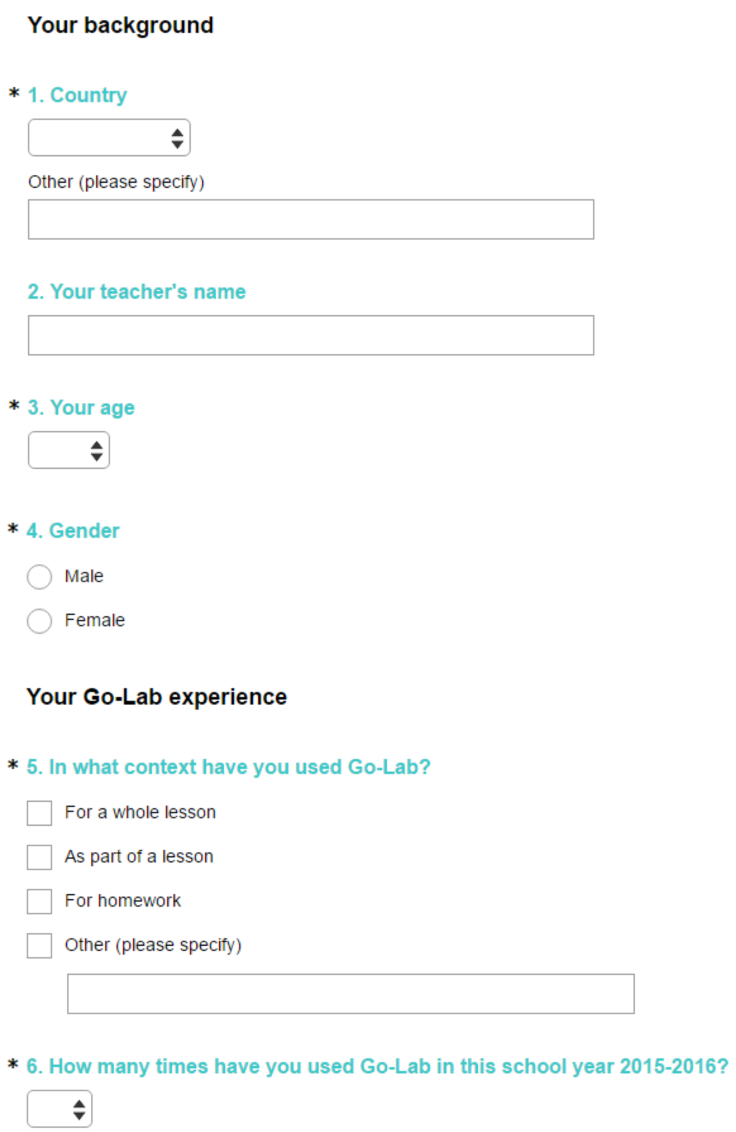
3.1 Introduction

As part of the Go-Lab evaluation process a post-questionnaire for students has been composed. According to project's aims, Go-Lab tries to provide students with opportunities to gain hands-on experience in science by conducting experiments using modern laboratory equipment and by doing so to deepen their knowledge in fundamental sciences, and motivate them to pursue scientific careers in the future.

The questions in the post-questionnaire focus on the value of science, technology and mathematics in students' life and in society. We are also interested students' school experience of these subjects as well as in their thoughts about modern science and technology jobs. Simple usability questions in relation to Golabz are also included.

3.1.1 Evaluation instrument

The EN version of the questionnaire that students have been asked to fill in after the completion of their Golabz experience can be found below in Figure 47.



Your background

* 1. Country

Other (please specify)

2. Your teacher's name

* 3. Your age

* 4. Gender

Male

Female

Your Go-Lab experience

* 5. In what context have you used Go-Lab?

For a whole lesson

As part of a lesson

For homework

Other (please specify)

* 6. How many times have you used Go-Lab in this school year 2015-2016?

7. Please specify which online laboratories or ILSs you have used (name and/or URL) in the course of the school year 2015-2016.

* **8. Science, technology and mathematics at your school:**

The statements below express different views on science, technology and mathematics in school.

Please indicate your agreement-disagreement with each of them by ticking one box for each statement.

	1: Strongly Disagree	2: Disagree	3: Neither Agree or Disagree	4: Agree	5: Strongly Agree
8.1. Using Go-Lab makes it easy for me to understand and learn school science and technology.	○	○	○	○	○
8.2. Using Go-Lab, I find school lessons in science and technology interesting	○	○	○	○	○
8.3. Using Go-Lab in learning school science and technology, will help me with everyday practical	○	○	○	○	○
8.4. Using Go-Lab makes school mathematics easier for me to understand and learn.	○	○	○	○	○
8.5. Using Go-Lab, I think school mathematics will have practical use in my daily life	○	○	○	○	○
8.6. Using Go-Lab in learning science, technology and mathematics at school makes it easy for me to understand the work of scientists and researchers	○	○	○	○	○
8.7. Using Go-Lab, I find mathematics interesting.	○	○	○	○	○
8.8. Using Go-Lab in school science, technology and mathematics help me discuss topical scientific issues with fellow pupils.	○	○	○	○	○
8.9. Using Go-Lab in school I learn about different career choices available in industry, science, technology and mathematics.	○	○	○	○	○

* **9. Practical work in science:**

The statements below express different view on science practical work in school.
Please indicate your agreement-disagreement with each of them by ticking one box for each statement.

	1: Strongly Disagree	2: Disagree	3: Neither Agree or Disagree	4: Agree	5: Strongly Agree
9.1. Using Go-Lab makes practical work in science exciting.	○	○	○	○	○
9.2. Using Go-Lab makes practical work in science good because I can work with my friends.	○	○	○	○	○
9.3. Using Go-Lab makes me like practical work in science because I can decide what to do myself.	○	○	○	○	○
9.4. I would like more practical work using Go-Lab in my science lessons.	○	○	○	○	○
9.5. We learn science better when we do practical work using Go-Lab.	○	○	○	○	○
9.6. I look forward to doing science practicals using Go-Lab	○	○	○	○	○

* **10. Science, technology and mathematics in the society:**

The statements below express different views on the value of science, technology and mathematics in society.
Please indicate your agreement-disagreement with each of them by ticking one box for each statement.

	1: Strongly Disagree	2: Disagree	3: Neither Agree or Disagree	4: Agree	5. Strongly Agree
10.1. Today all people, regardless of their career choices, need to learn science, mathematics and technology.	○	○	○	○	○
10.2. In the near future, our society will need more engineers, technicians and scientists.	○	○	○	○	○
10.3. Jobs in science, technology and mathematics can be very different and they need people with very different personal qualities and skills.	○	○	○	○	○

*** 11. Science, technology and mathematics careers:**

The statements below express different views on your attitudes regarding science, technology and mathematics careers. Please indicate your agreement-disagreement with each of them by ticking one box for each statement.

	Strongly disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
11.1 Learning science, technology and mathematics will help me get a good job.	○	○	○	○	○
11.2 Knowing science will give me a career advantage.	○	○	○	○	○
11.3 I will pursue a career in science, technology and mathematics.	○	○	○	○	○
11.4 I will use inquiry skills in my career.	○	○	○	○	○

*** 12. Learning with Go-Lab:**

For each of the following statements please indicate your extent of agreement.

	Strongly disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
12.1 Go-Lab as an online learning environment meets my requirements	○	○	○	○	○
12.2 Using Go-Lab for learning is a frustrating experience	○	○	○	○	○
12.3 It is easy to use the Go-Lab environment	○	○	○	○	○
12.4 Working with Go-Lab takes more time than usual	○	○	○	○	○

Done

Figure 47. Students' large-scale questionnaire.

3.1.2 Data sample

A total number of 677 students have filled in the questionnaire. Answers from students between 19-20 years old have been removed since they have not been directly targeted by the project so we ended up with a sample of 574 questionnaires. The split per country can be seen in Figure 48, where countries with no questionnaires have not been included.

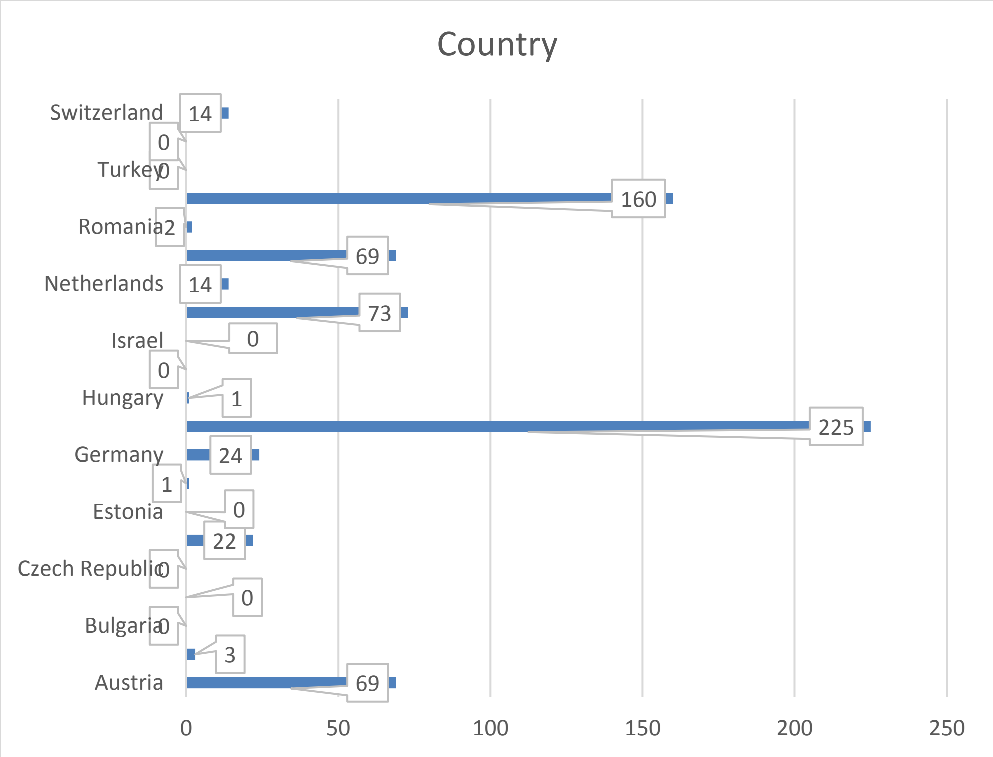


Figure 48. Students' large-scale questionnaire per country.

Age

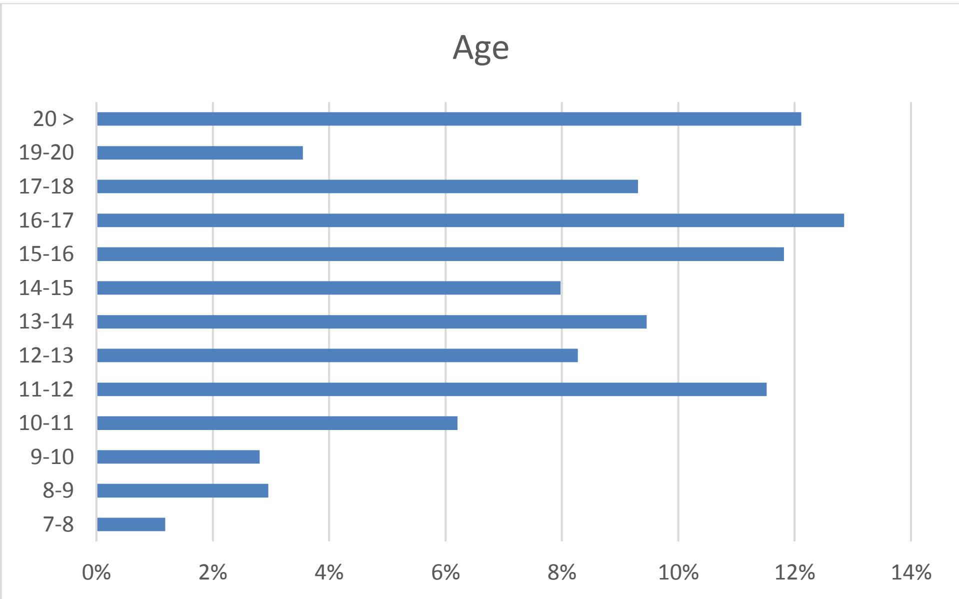


Figure 49. Responding students' per age.

In Figure 49 we provide an insight of the age groups comprising our students' sample. The majority of students, 60%, are between 13-18 years old with 7-12 years old, primary students, being at 28%.

When it comes to gender and as one can see in Figure 50, 47% of our respondents are males with 53% females.

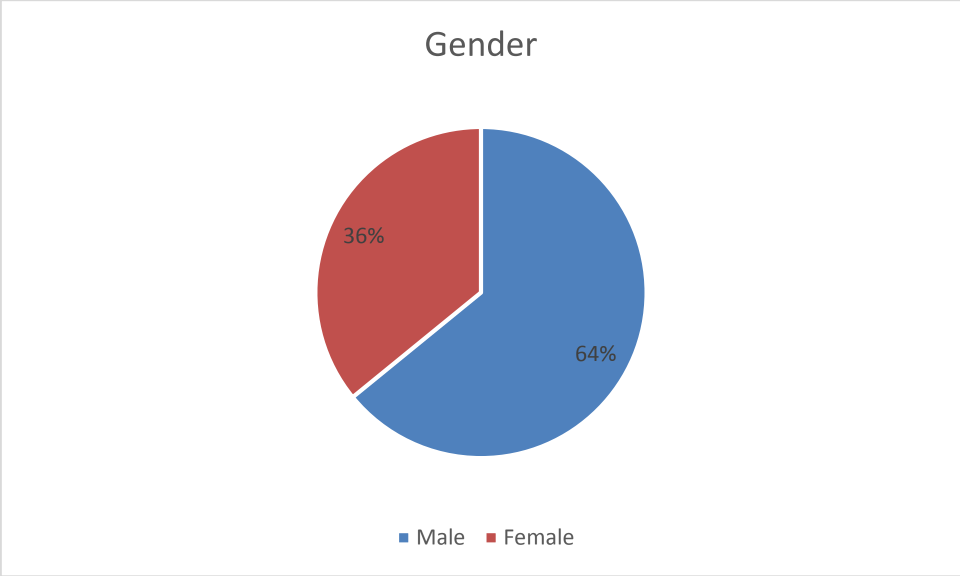


Figure 50. Students' gender balance.

3.1.3 Data analysis

3.1.3.1 Use of Go-Lab

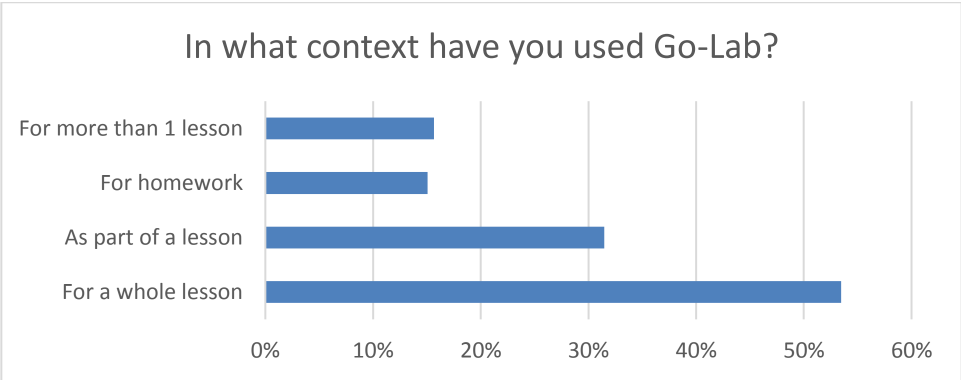


Figure 51

In Figure 52 we can see that more that 56% of the students have used Go-Lab for the entire duration of a lesson (45'-50') while 27% has used it as a lesson component. What is particularly interesting is that 13% of the students have used Go-Lab out of the classroom and as part of their homework while a similar percentage have used Go-Lab more than once in their classroom.

3.1.3.2 Frequency of Go-Lab use

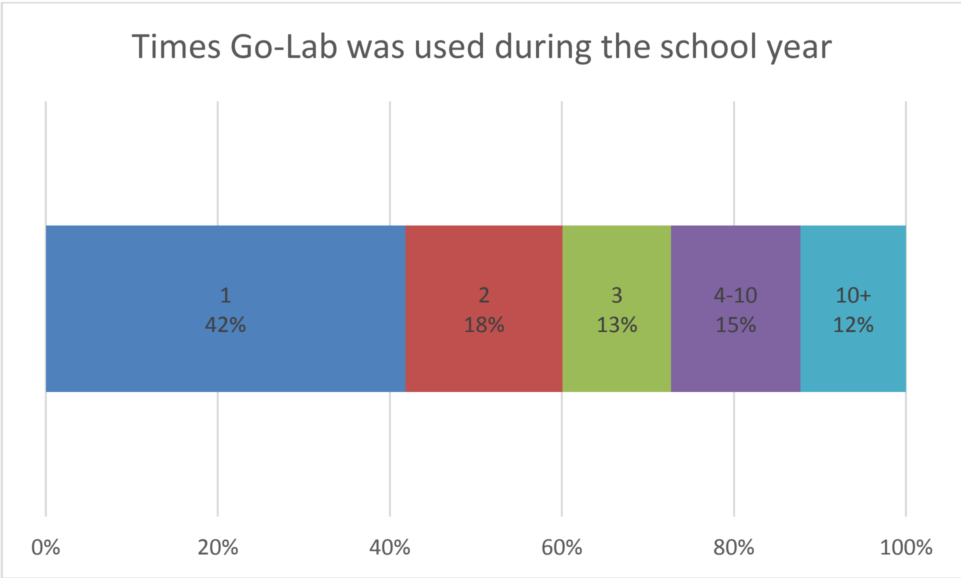


Figure 52. Students' frequency of Go-Lab use.

When it comes to the frequency of Go-Lab use and we can see in Figure 52, 36% of students have used Go-Lan only once during the school year. 21% have used it twice while 42% have used it for more than 3 times.

3.1.3.3 Use of Go-Lab & science, technology and mathematics teaching

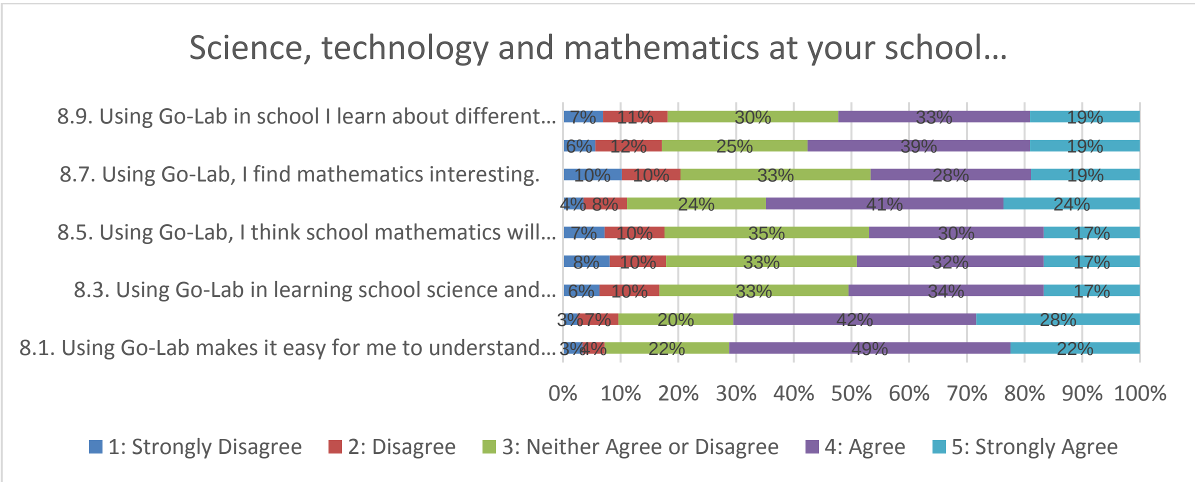


Figure 53. Students' views on use of Go-Lab in science, technology and mathematics at their school.

According to Figure 53, 52% of students agree that the use of Go-Lab in school helped them learn about different career choices available in industry, science, technology and mathematics with 58% stating that the use of Go-Lab facilitated the launch of discussions on the above mentioned topics among students. 65% of students have stated that Go-Lab helped them understand the work of scientists and researchers while 70% of students agreed that Go-Lab made their science and technology lessons more interesting. To strengthen this statement, a very similar percentage of 72% has agreed that using Go-Lab made it easy for them to understand and learn school science and technology.

What is particularly interesting for Go-Lab though is that approximately 25%-30% seem to be hesitant when it comes to the impact that Go-Lab have both during their school experience and their overall understanding and interest on school mathematics, science and technology. Some further insights on whether this hesitation is related to the frequency of use of the age will be of particular interest in order to identify the possible blockages.

3.1.3.4 Practical work

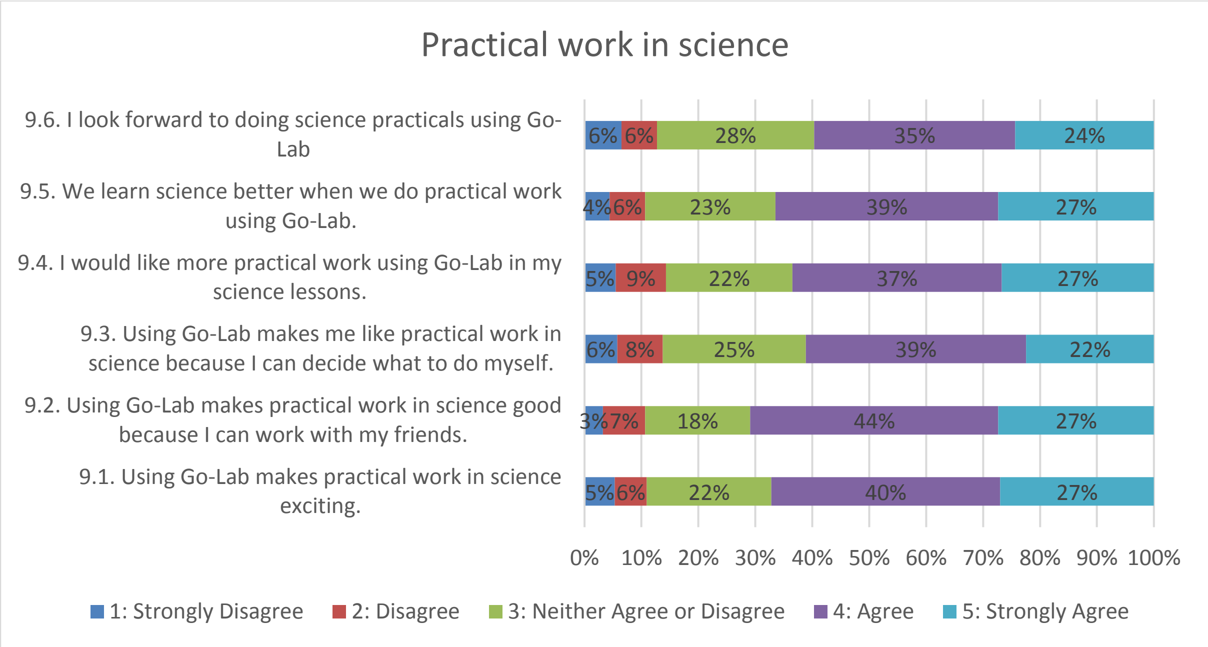


Figure 54. Students' views on practical use in science.

In Figure 54 we can see that 66% of the participating students agree that they learn science better when they do practical work with Go-Lab while 63% would like to do more practical work with it. 71% of the students appreciate the collaborative aspect of Go-Lab since it allows them to work with their friends and 67% believe that Go-Lab makes their practical work in science exciting. A 20%-25% remain undecided when it comes to the impact that Go-Lab has on their school practical work while an approximately 10% replied negatively.

3.1.3.5 Use of Go-Lab & science, technology and mathematics in the society

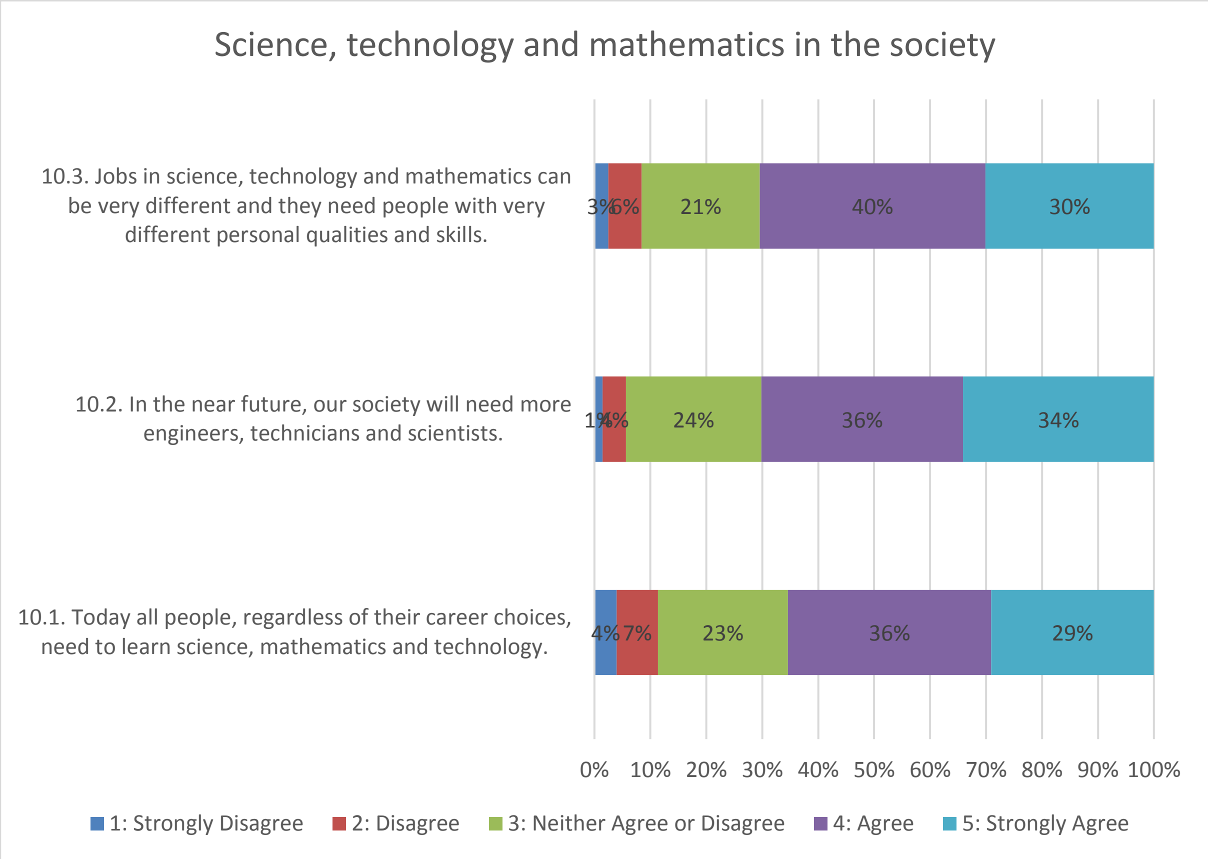


Figure 55. Students' views on science, technology and mathematics in the society.

When it comes to the use of Go-Lab & science, technology and mathematics in the society, see Figure 55, 72% of our respondents agree that in the near future, our society will need more engineers, technicians and scientists. A similar percentage, 71% of students, agree on the variety of personal qualities and skills that professionals in science, technology and mathematics need to have with only 3% disagreeing to that statement. In addition, 66% of students believe that in our days, all people, regardless their career choices need to learn science, mathematics and technology.

3.1.3.6 *Use of Go-Lab & science careers*

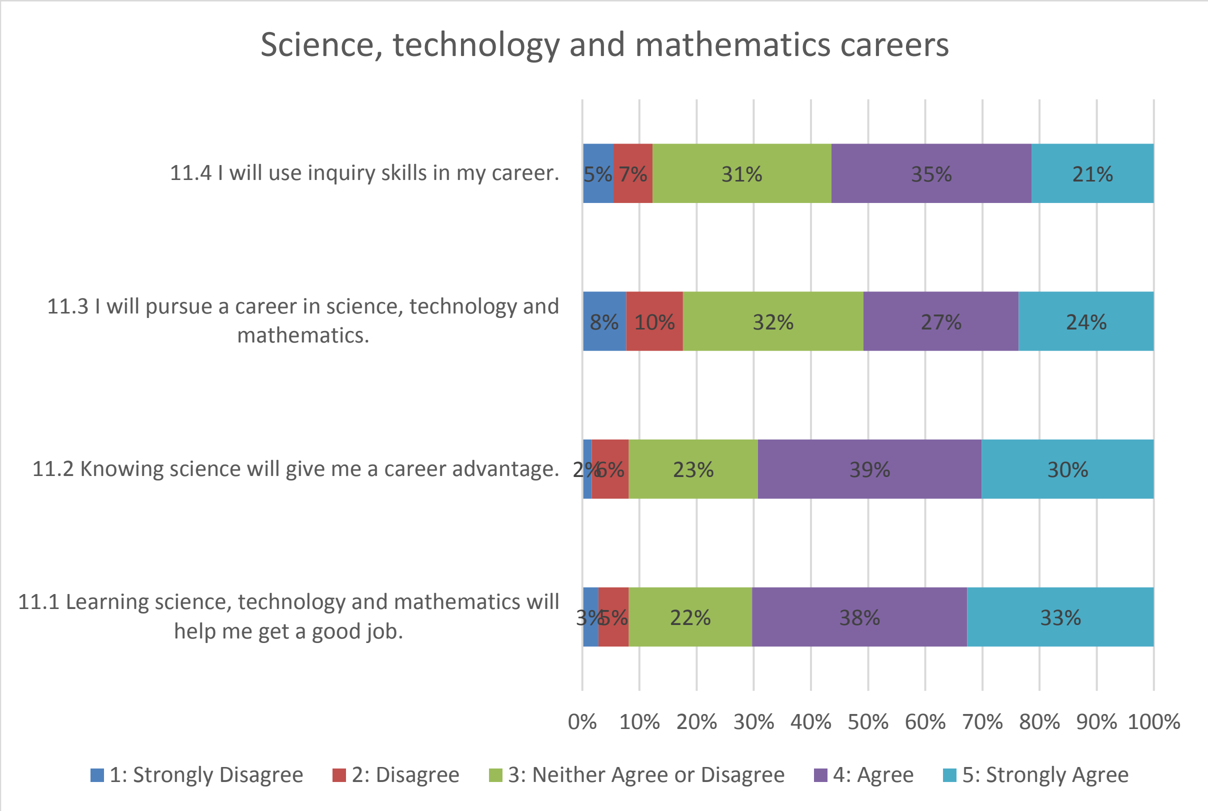


Figure 56. Students views on the use of science, technology and mathematics careers.

In Figure 56, 56% of the respondents state that they will use inquiry skills in their career with 32% being undecided. 52% of the respondents are willing to pursue a career in science, technology and mathematics with a large percentage of 30% being undecided and 17% rejecting this idea. Finally, more than 71% agree that knowing science will be a career advantage for them and will help them get a good job with less than 10% disagreeing.

3.1.3.7 Go-Lab usability

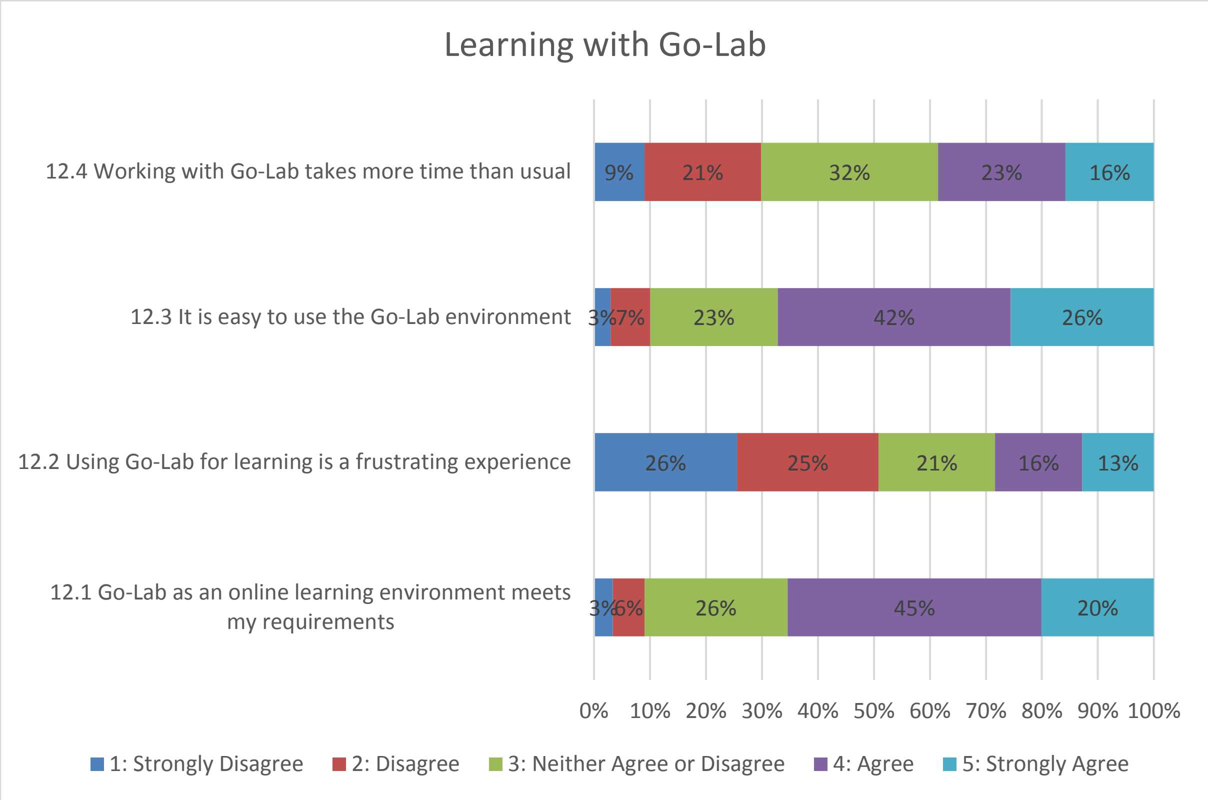


Figure 57. Usability of Go-Lab.

On the usability side and as we can see in Figure 57, 68% of the students find the Go-Lab environment easy to use while almost 40% found that working with go-Lab takes more time than usual. 30% found that the use of Go-Lab for learning is a frustrating experience which can be attributed to a series of factors including the need of more personalised guidance. Nevertheless, Go-Lab meets the online learning requirements of 65% of students.

4 Organisational evaluation

4.1 Introduction

The purpose of the WP8 case studies is to gather proof of Go-Lab implementations in schools while inspiring and convincing stakeholders to adopt the use of online and remote laboratories in classrooms across Europe. In this regard, case studies have been conducted in a wide range of countries and schools, providing an extensive and fruitful data source.

4.2 Complete case studies

4.2.1 Methodology

Case studies are divided per visit (ideally 2 per teacher) and include observations on both the instructor's and the students' activity, all recorded via an observation sheet; pre and post short interviews and a final interview with the instructor.

Observation sheets are divided in the following categories: organisation (e.g., preparation of instructor and efficient use of time), development (e.g., ownership over lesson and ILS methodology use), communication (e.g., language used by the instruction and verbal and non-verbal clarity), student interaction (e.g. motivation and interaction with the ILS) as well as a general overview of the strengths and weaknesses of the lesson. The interview guidelines used during the observations are included in the following section.

4.2.2 Instruments

Teachers' pre and post interviews – individual short interview protocol

The **Go-Lab teachers' pre and post interviews** are designed to offer educators the opportunity to reflect on their teaching and learning. These should be conducted shortly before AND after an individual observation.

While it is usually a good idea to record your interviews with a digital voice recorder (unless the interviewee complains or becomes clearly uncomfortable) you should always take notes and, if possible, transcribe it verbatim (in the same words originally used). Interviews should also be conducted in a quiet, comfortable environment. **Recordings will not be collected, instead we will accept interview transcriptions in English OR summaries of the interviews in English which will have to be sent back to the Go-Lab staff using the corresponding template (Template 1). Please note that we should receive two transcriptions OR summaries, in relation to the pre and post interviews.**

Teachers' pre interview

The pre teacher interview has to be conducted before any class observation takes place and is addressed to a teacher who is about to use Go-Lab tools in her classroom, Inquiry Learning Spaces (ILSs) in particular.

Tips for conducting the interview:

- Questions that are related to a single idea are always the better option. Try to frame every question with a different idea.
- Make sure to use vocabulary the interviewee understands and avoid any type of verbiage.

- Semi-structured interviews allow interviewees to give extra information not initially planned. In this particular case, they can enable a discursive approach so that teachers can share their vision of science / mathematics / technology-enhance learning / inquiry-based learning in a more general way.

Recommended questions for interviews completed BEFORE an observation.

1. Which were the objectives set for the lesson? What has preceded it?
2. Did you share an existing ILS or created a new ILS? In the former case, why did you chose it? Have you made any changes to it?
3. What is your experience in using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?
4. How do you intend to use the ILS? Please, provide with a brief description of the envisioned lesson structure. How much time do you expect to spend in each phase?
5. Could you tell me a few words about your students? In particular, what is their experience with Go-Lab and/or other technology-enhanced learning environments? And with inquiry-based learning?

Teachers post interview

The second teachers' interview should take place directly after the observation making reference refer to the recently-observed learning and teaching session.

Tips for conducting the interview:

- Try to articulate open-ended questions that cannot be responded with just one word or phrase and, in order to avoid vagueness and collect single ideas, make sure to formulate specific questions instead of "why" questions.
- Remind the interviewee you are thinking in particular about the learning session recently observed, with a focus on inquiry-based learning in science and math.
- For this interview, the interviewer should present the teacher with the option to select a relevant sequence of digital images. These will be presented on the device they were captured on, a laptop computer or as hard copy print-outs. These images should refer to the questions formulated below.

Recommended questions for interviews completed AFTER an observation

1. What is your opinion on the general development of the lesson?
2. Did the students achieve the outcomes set for them? Particularly, what did they learn?
3. Which were the dynamics of the students learning? Please describe them in terms of social dimension, collaboration between children etc.
4. Did you use the Go-Lab tools as you had intended to? Were there any changes to your original planning?
5. Did Go-Lab facilitate the achievement of the outcomes previously set? If so, how?
6. Did you, as a teacher, facilitate students' learning? If so, how?
7. What aspects of the lesson involved inquiry-based teaching and learning?
8. How did you evaluate the students' learning outcomes? How does this inform your planning?
9. Are any of the Go-Lab assessment apps usually used by teachers?
10. Would you like to do any other remarks about the usage of inquiry-based science/mathematics?

In relation to the images chosen by the teacher:

11. Why did you choose this image/these images? *It is advisable for the interviewer to ask about considering science/mathematics as separate areas of knowledge or in broader grouping; about links with other subject areas / cross-curriculum approach, etc.*

Teachers' final interview

The teacher third and final interview should be conducted after the completion of the 2 observations at a pre-defined time. If the interviewer is experienced, the outline may be used flexibly, with extra probing questions where it seems appropriate. **Please remember that recordings will not be collected but we will accept interview transcriptions in English OR summaries of the interviews in English which will have to be sent back to the Go-Lab staff in the appropriate template. (Template 1)**

Recommended questions for teachers' final interview

Please note the numbered questions below should always be asked during the interview while the others suggested questions remain optional. These are designed as follow up questions and as useful lines of enquiry in case the answers given by the teacher do not cover the content asked:

1. Please describe your experience with the Go-Lab project, so far.
   - When did you first encounter the Go-Lab project?
   - How have you profited from it? Could you mention particular examples of writing ILSs, using ILSs or publishing ILSs?
   - How have you used the ILSs? In class, as homework or as project work? Have you thought of any other modes of delivery?
   - How much professional support have you had?
   - Could you mention any particular good or bad experiences?
2. What are the best and worst aspects of Go-Lab, in your experience?
   - Creating ILS / Using ILS / Classroom issues / Technology issues / Usability issues / Learning issues / Inquiry based learning implementation
3. Drawing from your experience, how effective are the learning outcomes from Go-Lab?
   - When has it been most effective? And least effective?
   - Has the Go-Lab technology and its usability ever been a distraction from science learning?
4. Do students enjoy learning in this manner?
5. Do you think other science teachers would have similar experiences? If not, why?
6. How do you expect Go-Lab to be adopted in your school in the coming year or two? What advantages and disadvantages would it bring?
   - In which subject areas would you adopt it?
   - Through which teachers?
   - In which lesson(s)? Subject(s)? Age range(s)?
   - Do you think you spent more or less time in lesson planning when using Go-Lab compared to using real labs?
7. Do you think it takes students more or less time to learn using Go-Lab compared to using real labs?
8. Do you foresee any major obstacles to the widespread adoption of Go-Lab in science teaching practices?

Head of school/organization interview – individual protocol

The observation should conclude with the head of school interview (responsible for the educational organization where teachers have implemented the Go-Lab tools). **Please note that, in the same way as with the teachers' interviews, recordings will not be collected but we will accept interview transcriptions in English OR summaries of the interviews in English which will have to be sent back to the Go-Lab staff in the appropriate template. (Template 2)**

Please keep in mind that the **recommended questions for Heads of School** below are designed to generate data on the following topics.

- **RQ1:** How does the use of ILSs in a school (including non-MST teachers) affect the schools' attitudes (awareness) and motivation towards inquiry learning in general and to online labs in particular?
- **RQ2:** How does the availability of the Go-Lab portal (www.golabz.eu) in a school affects the schools' attitudes (in particular, their awareness and motivation) towards inquiry learning and online labs?
- **RQ3:** How does the availability of Go-Lab affect daily practice in a school? How does it affect the attitudes of the school towards STEM?

For this interview, both the research questions (above) and the recommended questions (below) can be used.

Recommended questions for Heads of School final interview:

1. What is your role within the organization (or relationship with the organization)?
2. Had you used or heard about online laboratories before your Go-Lab experience?
3. How would you characterize the implementation of IBSE in your school before experiencing with Go-Lab? Where you familiar with the concepts and the practices used? Are these frequently or rarely used?
4. How would you characterize your experience with the implementation of Go-Lab in your school? Was it positive/negative? Useful/ineffective? Please provide with reasoning for each of your statements.
5. Did Go-Lab have any impact on your understanding of inquiry based learning?
6. How does the availability of the Go-Lab tools and ILSs in a school affect the schools' attitudes (awareness) and motivation towards inquiry learning and online labs?
7. Did the teachers in your school find it easy to incorporate the use of Go-Lab in their curriculum? How many teachers have used it? What are their specializations?
8. How would you characterize the impact of Go-Lab on students? Why?
9. How do you plan to use Go-Lab in the future?

Observer sheet

Observation techniques are used in evaluation methodologies as a way to help the systematic description of patterns and behaviours in a chosen social setting and as a way to depict a "written photograph" of the situation under study. **Particularly, during Go-Lab observations, while the group will be aware of the evaluation activities, the observer will NOT be asked to participate nor to influence the groups' dynamics.** The observer should act as a careful spectator and maintain a sense of objectivity throughout the whole activity.

For this observation, the attached sheet (Template 3) must be filled in and sent back to the Go-Lab staff. It should function both as an evaluation tool for observers to help them

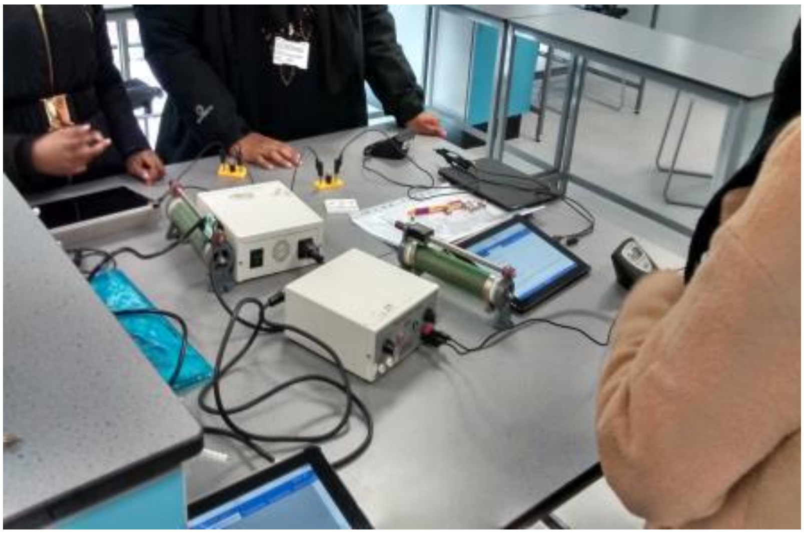
collect data and for researchers to help them have a better understanding of the context under study. During this session, the observer should also collect notes on its development, taking into account the template boxes. After the completion of the observation, the teacher and the observer should meet in order to discuss the session and complete the templates. This should be an opportunity to pose questions and to carry an honest conversation about both parties' expectations and reflections.

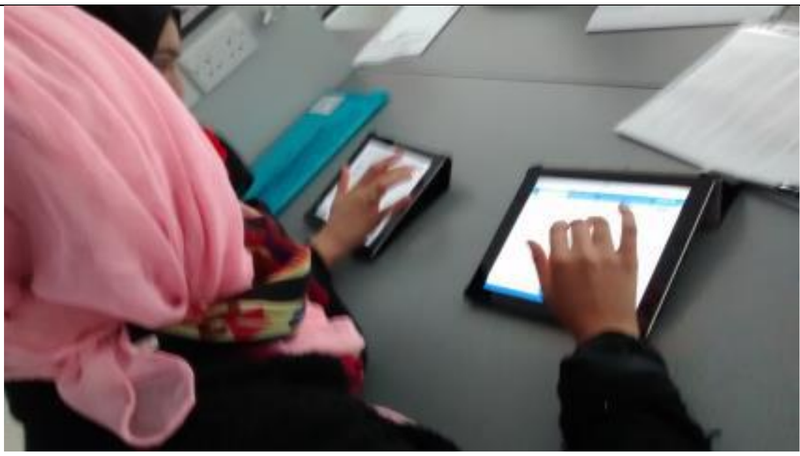
4.2.3 Case studies per country

4.2.3.1 United Kingdom (by Rob Edlin-White, Matthias Heintz, Effie Law)

DESCRIPTION

Title	Implementation of complex (10 lesson) ILS (WP8 Case study)
Country City/Region	UK, Birmingham
Working language	English
Start/End Date	29/2/2016 – 14/3/2016
Organizing Institute	University of Leicester
Coordinator name and email	Rob Edlin-White rew25@le.ac.uk Matthias Heintz mmh21@le.ac.uk Effie Law lcl9@leicester.ac.uk
Activity Form	In school activity
Activity Type	Implementation activity (WP8 Case study)
School profile	Joseph Chamberlain sixth form college, Birmingham, England http://www.jcc.ac.uk/
Total number of teachers/schools	1 teacher, 15 students (aged 17-18)
Implemented online labs	Implementation of a complex (10-lesson) ILS involving two labs: electrical circuits and resistivity. ILS: http://graasp.eu/ils/56ab584495c4a25b80e1ec42/?lang=en
Brief description	Following attendance at a Go-Lab teacher workshop at the University of Leicester, a teacher had (with some support) created a large and complex ILS to use for a 10-hour module of a BTEC course, delivered over a period of 2 weeks, on the subject of electrical circuits, using a blended learning approach – some real equipment, and two online labs. ULeic researchers visited the school to observe and support some of these classes (including the first and the last), to record data, conduct formal and informal interviews and administer questionnaires.

Learning outcomes	Once the students had completed the ILS and the work was marked, **71% of the students gained the distinction grade** first time, **compared to 53%** that attained a distinction in the previous assignment. The teacher remarked (and we also observed) that student engagement, creativity and collaboration was very high, with students willingly working on the ILS from home in order to complete the work. Additionally, the teacher believed that the students were becoming more independent of didactic input in their thinking and in their approach to learning. From a brief discussion session and on feedback forms, it was clear that students appreciated using both "real" and "virtual" labs. They discussed the benefits and limitations of each. The consensus was that both sorts of labs are valuable and that blending the two where possible is a good idea.
Photos or other relevant material	 

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEWS

Information box

General information	
Dates	10/3/2016
Name of teacher/	Sue de Cicco
Years of experience in teaching	18
Main teaching subject(s)	Chemistry
Age(s) of students	16-18
Experience delivering lessons on ICT	No prior experience

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

For the students to put together circuits; to understand that real circuits and theoretical ones don't match perfectly and to compare them.

The criteria they needed to complete were:

Pass: To assemble series and parallel circuits, and to carry out essential electrical measurements on an assembled circuit.

Merit: Calculate current, potential difference and resistance.

Distinction: Compare the accuracy of measured values.

Most of the students won't have done any electrical circuit work for several years and many will have forgotten all about it.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?
No experience of online lessons, but have occasionally used online simulations of chemical equipment in a lesson. But this is with me talking the students through it, not letting them do things in their own way and at their own pace as they do in Go-Lab. I also used Labskills a bit.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?
I created a brand new ILS as you saw.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)
They will work through the ILS during 10 lessons spread over a fortnight. The early lessons will use real lab equipment but soon they will be using the online labs so this is a case of blended learning. The ILs will be used for experimental panning and recording results in all experiments whether conducted in the online or real labs.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?
They are quite a capable group, but not the highest achievers at science else they'd be on the A level course. We've never given them online lessons before and they have no experience of Inquiry based Learning.

POST-INTERVIEW
How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?
The students were unsure at first regarding the lessons using online content as this was the first time an assignment had been presented this way in the college. Giving the students an overall idea of the lessons, they became quickly aware of the concept and time limit of the assignment and online work. They got the hang of using the ILS quite quickly, helping each other out a bit to start with but rapidly achieving independence. By the end the students were getting a lot out of it, including self-motivated self-study. They made really good progress.

I was able to step back as a teacher, more than I was expecting. As students progressed through the ILS my role became increasingly guide and facilitator rather than instructor. The students' own creativity began to show during the lessons, and they became more inquisitive regarding the setup of electric circuits and the outcomes they should expect

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?
Almost exactly to plan – except when data was lost from tables! It was good to have some hands-on real labs before the virtual.

How did Go-Lab facilitate the achievement of these outcomes?
A lot. Mainly because it was online and students would see how to achieve a distinction mark. Also this method of delivery encourages independent learning, and needs a new style of teaching which will suit some teachers' natural styles, but others will adapt.

Concerning the images the teacher has chosen (if appropriate): Why did you choose this image / these images?
She chose an image of a student working at a workbench with real electrical equipment and an iPad showing the Go-Lab ILS. It exemplifies the blended learning approach and also shows the enthusiasm they had.

What were the students learning?
The students were learning all the material relevant for BTEC module in Electrical circuits – practical and theoretical. This can be found on the Pearson website.[2]

What aspects of the lesson involved inquiry-based teaching and learning?
Playing with the lab! They had to work out how to build all the circuits they needed with very little guidance. As regards experimental design, they were told what to achieve but not how to achieve it.

How were the students learning?
To start with they were quite sociable, as they learned to use the online system and helped each other out a bit. But as time went on, especially as they progressed at different speeds, the work became more individual. At the end I had included the Padlet app to encourage them to share their results, and this worked very well.

How were you evaluating children's learning and how does this inform your planning?
I was monitoring their progress verbally and also by wandering around and watching what they were doing and providing any appropriate support. Wandering, mingling, questioning, observing. I was also checking their online products either by signing on or looking at screenshots. Later I will mark their work against the BTEC criteria. I want to get more confident at using the teacher apps to monitor progress.

How were you facilitating learning?
I was able to step back as a teacher, more than I was expecting. As students progressed through the ILS my role became increasingly guide and facilitator rather than instructor. The students' own creativity began to show during the lessons, and they became more inquisitive regarding the setup of electric circuits and the outcomes they should expect. By using both real equipment and online labs, the students gained a more profound understanding of the limits of the real electric circuit equipment and the results it produced. They enjoyed using the ILS, and were able to gain more insight into the problems scientists and engineers face every day when dealing with this than they would have if I had told them.

Minimal support was given to tell students how to construct different circuits. This encouraged them to not only refer back to the reference YouTube videos, but also to solve the problem themselves. I was on hand if they struggled, but as part of my developing pedagogical approach, I often asked they to 'try it themselves' first. For most of the students this worked, and by the time they reached circuit 11 they were confident in their practical abilities. By doing this, all the students were able to achieve the pass criteria with very little input from myself. I was also able to allow them to develop their own understanding of the circuits and why some

2 http://qualifications.pearson.com/en/qualifications/btec-nationals/applied-science-2010.html

worked better than others, with some students producing their own circuits in an attempt to develop their understanding more.

Is there anything else you would like to tell me about using inquiry-based science/mathematics?
It was an interesting, novel and slightly strange way to teach. I enjoyed it though and want to do it again. The students enjoyed it too and took much more responsibility and ownership of their own learning experience.

OBSERVER SHEET

Go-Lab Observation	
Teacher name	Sue de Cicco
Subject taught	Electrical Circuits in this lesson (normally chemistry)
ILS (s) used	Constructing Circuits - Btec Level 3 - Unit 17 http://graasp.eu/ils/56ab584495c4a25b80e1ec42/?lang=en
Observation date	10/3/2016
Observation time	14:30 – 15:30
Nr. of students present	17

Please check the appropriate column for each item in a section, where:
1.) Y = The measure was observed
2.) N = The measure was not observed
3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	
X			Instructor is well prepared for class (apps and computers prepared)	ILS very well prepared. Some of the desktop computers not working but 17 pupils and 24 computers so there were enough.
X			Instructor appears to be confident to use the selected ILS	Yes .She had written it herself.
X			Instructor uses a relevant ILS for the development of his classes	Very clearly focussed on the curriculum requirements.

Development

Y	N	NA	Measure	Notes
		X	Instructor uses the phases of the ILS consecutively	The students used the phases consecutively as far as we could tell, navigating their way through at their own pace. The teacher monitors progress using Learning Analytics / Classroom management apps a bit, but also by wandering and observing.
X			Instructor switches from one phase to another (and goes back if needed)	Except it was students, not the instructor.
X			Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	Not observed but yes, sure she did. The students started this lesson at the point in the ILS where they'd finished the previous one.

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	Very!
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
	X		Students work individually from the beginning	Lots of collaboration when encouraged by teacher or ILS (e.g. Padlet app). Mainly independent when appropriate.
X			Students appear to be clear about the task	Mainly …
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	Enough spare computers in the room to cope with a few not working. But – one or two students found ILS had lost data.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
	X		Students doubts are managed effectively	Not always. Lost data could not be resolved during the lesson. Teacher described a contingency plan involving screenshots.
X			Students are familiar with ILS	
X			Students seem to be motivated with the ILS	Very. Some asking whether they can use it in their own time.

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	Enthusiastic and forgiving!
X			Students are interested with the problem (specific ILS)	
	X		Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Students participated & collaborated when they got to the Padlet app.
X			Students seem to be supportive during the activity	

General comments
Major issues observed: A couple of students seemed to lose data from the table app within the ILS. (this was much worse in the final lesson a few days later when lots of data was lost)
Major outcomes observed: Students loved the fact that the lab has all its components working first time, and also has an endless free supply of working new light bulbs if they manage to blow one out. They said this is much better than the real lab equipment. Also the meters are accurate and easy to use and read. All the data from the module is stored in one place so there's no paperwork to lose.
Additional comments: None

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	10/3/2016
Name of teacher	Sue de Cicco
Years of experience in teaching	18
Main teaching subject(s)	Chemistry
Age(s) of students	16-18
Experience delivering lessons on ICT	No prior experience

Interview summary or transcription

Please describe your experience of Go-Lab so far

I was first made aware of Go-Lab after attending an evening workshop at Leicester University in April 2015. I instantly saw the benefits of using the programme and looked at my own teaching to see how they could be incorporated. I used the electrical circuits lab standalone in class very soon afterwards with great success. As a follow on from this, I invited the Leicester team into the college I worked at in order to provide additional training for my work colleagues. This session was in august 2014 and was very encouraging. On discussion with other members teaching the BTEC course, I found an area where I could experiment with an ILS and incorporate this into an appropriate unit.

When beginning to plan the ILS, I wanted to produce something that would allow the students to discover their own understanding of electric circuits with a reliable circuit and equipment. Unfortunately, the real lab equipment suffers from the students' lack of care and as such are notorious in their unreliability. This being the case, I wanted the students to have an experience of using the real circuits and the problems they created, but to also have the opportunity to see circuits as they should be and gain some reliable results from this in which to compare. The students could then also compare the results from both circuits.

Looking at the online labs available, I decided upon using the electrical circuit lab and the resistivity lab as both of them were able to mirror the practicals I requested the class to perform. The students would be tasked to construct 11 different electrical circuits, and fortunately, 10 of these could be reproduced using these 2 labs. By both performing the labs online, and using the table tool available, the students should be able to store all their information online. This would hopefully reduce the problems faced as a teacher when students attend lessons with lost or missing data from the previous lessons.

I wrote most of the ILS unaided but had some support from the University of Leicester to finish it off and refine it.

The online lessons were delivered mainly in lessons in computer rooms, but some students also used the ILS from home. It was unusual for me to have students asking if they could do it as homework! The students were much more engaged and active than usual and enjoyed learning this way and appeared to be taking much more interest in their own learning than would normally be the case. Unfortunately on the last day there was a glitch in the system which meant their data was lost which put some of them off the system a bit. However I was able to mark their work based on screenshots. Apart from that it was generally a good experience. It took a long time to write the ILS but now I have the skills, future ones will be much quicker. The students got better grades than I would have expected so it was a big success.

What are the best and worst aspects of Go-Lab in your experience?
The best aspect is that the students worked independently, at their own pace, and with high motivation. Also they can use it from anywhere – e.g. homework if they want to.

The worst part was that we had poor and inconsistent technology; old laptops, iPads, or desktops with different operating software, some of which seemed to work better with Go-Lab than others. Also the Internet is sometimes slow in our college, and we had that horrible bug on the last day which lost the students' work.

- Creating ILS – goodish – will be faster next time
- Using ILS – excellent experience.
- Classroom issues – the students were very well behaved, and didn't use the computers for other stuff.
- Technology issues – some infrastructure problems causing slowdowns, + problem with data going missing from tables described above
- Usability issues – nothing major for students – they helped each other to start with, and quickly got to grips with it.
- Learning issues – it went very well.
- Inquiry based learning – I incorporated thus as much as the curriculum requirements allowed.

How effective are the learning outcomes from Go-Lab in your experience?
It's most effective when you have a very clear pattern and a lesson prepared. Least effective when you just show them the portal and let them have a play – they don't achieve much.

Usability wasn't really a problem as I avoided some of the complicated apps, but the slow loading was a frustration at times, and the table bug. Science teachers are good at adapting when things go wrong though; real labs have lots of problems too.

Do the students enjoy learning in this way?
Yes, they really, really enjoy it. They were even asking if they could carry on doing it at home. In fact, I want to create a new ILS this summer on rates of reaction using the collision theory lab.

Do you think other science teachers would have similar experiences? If not, why not?
Some but not all, depends how good they are with computer technology, and how confident. Some are stuck in their ways and can find big changes difficult.

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?
My electrical circuit ILS is being rolled out to more classes (6) next year. We're also looking at more physics labs, and another one for chemistry; I said – the one about rates of reaction based on the collision theory lab.

Everything will be for 16-17 or 17-18 years olds as we're a 6th form college.

The ILS took me more time to create than I would normally spend on a module of this size, but I got most of that time back in the lessons because they almost run themselves with me just being there to support, monitor and encourage, but not to deliver. I think it will be quicker to write a second ILS now I'm up to speed. I think the students learned faster than they would in a proper lab though.

Do you foresee any major obstacles to widespread adoption of Go-Lab for science teaching?
Most teachers haven't heard of it. It needs more awareness and publicity. I will be presenting to the science department next term, about my ILS and also about the Summer School.

HEAD OF SCHOOL INTERVIEW

Information box

General information	
Dates	10th March 2015
Name of Head of School	
Years of experience in education	

Interview summary or transcription

1. **What is your role within the organisation (or relationship with the organization)?**

Head of Science (and biology teacher). I have 14 teaching staff and 3 laboratory technicians.

2. **Have you used/heard of online laboratories before your Go-Lab experience?**

Yes. I have used Utah Genetics, and also the Drosophila lab. However, I have only used the labs alone, not full online lessons.

3. **How would you characterize the implementation of IBSE in your school, before the Go-Lab experience? Familiarity with the concept and practice or not; Frequent/rare use**

There has been no prior experience of it here, but some interest for vocational students.

4. **How would you characterize your experience with the implementation of Go-Lab in your school? Positive/negative, useful/not useful and why?**

Very positive. This allowed teachers to be far more creative in their approach, and it was also very refreshing for students. We're expecting an improvement in attainment levels. It has re-energised the group.

5. Did Go-Lab have any impact on your understanding of inquiry based learning?
Not as yet.

6. How does the availability of the Go-Lab tools and ILSs in a school affect the schools' attitudes (awareness) and motivation towards inquiry learning and online labs?
It's probably too early to say, but there was considerable interest in the workshop you did here.

7. Did the teachers in your school find it easy to incorporate the use of Go-Lab in their curriculum? How many teachers have used it? What are their specialisms?
Definitely – especially vocational. We're considering it for the new A-level specification too.

8. How would you characterise the impact of Go-Lab on the students? Why?
Positive and encouraging. Students have given unsolicited positive feedback. They like the safety of online labs.

9. How do you plan to use Go-Lab in the future?
We're looking at a simpler ILS for level 2 (GCSE) using the Drosophila lab. We may look at some others in chemistry. Geoff is going to use Sue's existing ILS.

10. Any other points?
I like blended learning – using real and online labs.

Go-Lab lessons could also be useful for pre-lab work, or for absent students.

Note that teachers have varied levels of computer skills and some have a strong preference for safe ways of delivering lessons.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

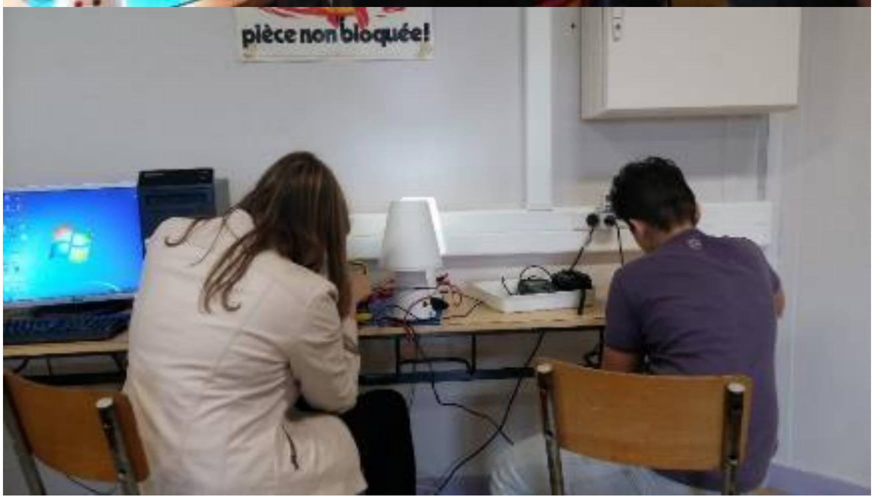
- The ILS was very complex and very thoughtfully constructed by the teacher to fit the curriculum requirements for electrical circuits. It consisted of 10 lessons worth of work.
- It was very well received by students, teacher and Head of Science, and also resulted in greater educational achievement (better marks) than expected.
- Some technical problems (since resolved) on the last day created a negative bias in the student questionnaire responses. Observation and engagement by teacher and ULEIC observers in previous lessons suggested a high level of acceptance and engagement.
- The teacher thoroughly enjoyed the whole experience and noted that the use of online inquiry-based learning brings about a big change in learning style for the students (self-paced and taking on more responsibility for their own learning) and for the teacher (role moves towards encouraging, supporting, observing, monitoring, questioning; much less didactic).
- The college wants to expand its use of Go-Lab into other ILSs as well as more uses of this one. The teacher wants to publicise Go-Lab to other teachers within and beyond the college.

4.2.3.2 France (by Teodora Ioan, Enrique Martin)

DESCRIPTION

Title	WP8 – Case study: Collège Le Marin
Country City/Region	France, Le Mans
Working language	English/French (primarily)
Start/End Date	27/5/2016 – 10/6/2016
Organizing Institute	EUN
Coordinator name and email	Teodora Ioan teodora.ioan@eun.org Enrique Martin enrique.martin@eun.org Evita Tasiopoulou evita.tasiopoulou@eun.org
Activity Form	In school activity
Activity Type	Implementation activity (WP8 Case study)
School profile	College Le Marin, Le Mans, France. http://clg-lemarin.sarthe.e-lyco.fr/
Total number of teachers/schools	1 teacher, 18 students (9+9)
Implemented online labs	Observation1: Climate Change – Greenhouse effect http://graasp.eu/spaces/5715d60290a9a86163dc0b92 Observation 2: http://graasp.eu/spaces/57547c3d616d921cbcd38b8b
Brief description	The implementation of the case study was organized within a predefined collection of qualitative and quantitative data, during the use of the Go-Lab ILS in a classroom, including: individual short teacher interviews per observation (pre and post), an observer sheet to be completed per observation, a final interview at the end of the second observation, a students' questionnaire and an interview with the Head of School. The items in students' questionnaire focused on students' attitudes and motivation towards STEM education.

Learning outcomes	The ILS acted as a tool to personalize the student work, enabling the teacher to help students individually. It also served as a great tool when switching from French to English during the lesson. All students were able to achieve the intended outcomes set by the teacher. Students enjoyed and were involved in the activity, even those with attention issues or behavioural problems were finally engaged and completed the ILSs.
Photos or other relevant material	Observation 1:   

	Observation 2:   

TEACHER INDIVIDUAL PRE & POST SHORT INTERVIEW (Observation 1)

Information box

General information	
Dates	27/05/2016
Name of teacher/	Mohamed Oubella
Years of experience in teaching	20
Main teaching subject(s)	Technology and ICT
Age(s) of students	All ages in secondary
Experience delivering lessons on ICT	Regular user of ILSs

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

The objectives of this lesson are to make students more sensitive towards climate change and the greenhouse effect, as well as raise their awareness on how small actions can contribute to save our planet. They will also see how they can involve their parents and neighbours in this effort.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

For the past 5+ years the teacher has been involved in European Projects in STEM education. He initially started using the Scientix repository to find and use various resources to build his lessons. Now he shares his experience in ICT tools with his colleagues and likes to use these tools to build fully digital lessons or in combination with hands-on activities.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

In his activity he has done both, but for this lesson he created one from scratch. When he adapted an existing ILS he took into consideration how the ILS relates to the subject of the lesson and how advanced his students are in that particular topic. Adaptions to the ILS concern changes in the tools used and simplifying sentences (if he kept in English) or translating in French.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

The teacher was planning to do only the first part of the lesson, up until Conceptualization as the lesson takes longer than 1 didactical hour and after the first phases, students will need to go back home and ask their parents various questions about their household habits so that they can input that data into the ILS.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

In the case of IBL, this class uses it in their Technology class with this teacher. With other teachers, they just go through the steps but they don’t use various ICT tools to support these steps. This particular class of students has 2+ years of experience in using Go-Lab. Their progress was gradual, tentative in the 1st year but they grew more and more with each school year and they also fill in questionnaires.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

Because the ILS was in English, the teacher felt that they studied more English than greenhouse effect in that lesson (students sometimes got stuck with the foreign language and they lost time going through English vocabulary – some activities in the ILS also included activities that required input in English). The students also reinforced what they learned in previous lessons with their physics teacher. Because of this, this teacher wanted to use this topic as a transversal one and offered them a different perspective on the greenhouse effect.

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?

He used Go-Lab as planned mostly. Students had to watch a video, extract information from it and try to find by themselves the relationship between daily choices and climate change. The deviation consisted in using a simplified version of the ILS (in the ILS, Orientation 2 instead of Orientation 1).

How did Go-Lab facilitate the achievement of these outcomes?

It acted like a tool to personalize the student work and as a teacher you can help them individually. It also facilitates your way of teaching. With these ICT tools you can also switch easily from English to French.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Mohamed Oubella
Subject taught:	Technology & ICT
ILS (s) used:	Climate change and greenhouse effect http://graasp.eu/spaces/5715d60290a9a86163dc0b92
Observation date:	27/05/2016
Observation time:	13h30
Nr. of students present:	9

Please check the appropriate column for each item in a section, where:

1.) **Y = The measure was observed**
2.) **N = The measure was not observed**
3.) **NA = The measure was not applicable**

Organization

Y	N	NA	Measure	Notes
	X		Instructor uses class time efficiently	Computers were turned off before the lesson.
X			Instructor is well prepared for class (apps and computers prepared)	Has the same ILS for different grade levels of his classes.
X			Instructor appears to be confident to use the selected ILS	ILS has been prepared at least 1 month ago.
X			Instructor uses a relevant ILS for the development of his classes	

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
		X	Instructor switches from one phase to another (and goes back if needed)	
		X	Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	Connects to other subjects of his colleagues, reminds students of what they studied in other subjects.

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
		X	Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	Both in English and French.

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
	X		Students work individually from the beginning	Students start as a group for the Orientation phase and then go to work at computers, either in pairs or individually.
X			Students appear to be clear about the task	
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	Even though doubtful about using their English, students are encouraged and talked through it.
X			Students are familiar with ILS	
X			Students seem to be motivated with the ILS	

Student behaviour

Y	N	NA	Measure	Notes
		X	Students are enthusiastic about the task (online ILS)	
		X	Students are interested with the problem (specific ILS)	
	?		Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Class is managed effectively, students participate and are supported equally, the small numbers of students also helps towards class management.
X			Students seem to be supportive during the activity	Students help each other throughout the class.

TEACHER INDIVIDUAL PRE & POST INTERVIEW (Observation 2)

Information box

General information	
Dates	27/05/2016
Name of teacher/	Mohamed Oubella
Years of experience in teaching	20
Main teaching subject(s)	Technology and ICT
Age(s) of students	All ages in secondary
Experience delivering lessons on ICT	Regular user of ILSs

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

In this lesson students will learn about energy efficiency in the context of the greenhouse effect. They build upon their last lesson and go into more detail into what are some of the human causes of the greenhouse effect and also see and measure a practical application of this, consisting of measuring the power consumption of four different types of light bulbs. This lesson consists of hands on activities integrated into an ILS which use knowledge from the electricity Physics subject they studied with another teacher.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

For the past 5+ years the teacher has been involved in European Projects in STEM education. He initially started using the Scientix repository to find and use various resources to build his lessons. Now he shares his experience in ICT tools with his colleagues and likes to use these tools to build fully digital lessons or in combination with hands-on activities.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

In his activity he has done both, but for this lesson he created one from scratch. When he adapted an existing ILS he took into consideration how the ILS relates to the subject of the lesson and how advanced his students are in that particular topic. Adaptions to the ILS concern changes in the tools used and simplifying sentences (if he kept in English) or translating in French.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

He will also do only half of the lesson as it requires two didactical hours to complete.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

The students achieved all the intended outcomes he had set for them: they had to briefly remember core ideas about the greenhouse effect and human causes as well as electric circuits studied with another teacher. Then they had to measure the electricity in four different lamps using various hands on professional tools. After they did these measurements they discussed briefly some first conclusions they have about these lamps (what types of bulbs consume more, etc.) and they will continue in their next lesson.

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?

No deviations from the planning.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Mohamed Oubella
Subject taught:	Technology & ICT
ILS (s) used:	Climate change and greenhouse effect http://graasp.eu/spaces/57547c3d616d921cbcd38b8b
Observation date:	10/06/2016
Observation time:	13h30
Nr. of students present:	9

Please check the appropriate column for each item in a section, where:

1.) Y = The measure was observed

2.) N = The measure was not observed

3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
	X		Instructor uses class time efficiently	We were late for class, computers are turned off before class.
X			Instructor is well prepared for class (apps and computers prepared)	The hands on activities are already prepared on the desks.
X			Instructor appears to be confident to use the selected ILS	
X			Instructor uses a relevant ILS for the development of his classes	

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
X			Instructor switches from one phase to another (and goes back if needed)	
X			Instructor seems to be in control of all the phases of the ILS	Students advanced in different rhythms and it's difficult to keep the same pace with the entire class.
X			Instructor connects the ILS to prior classes or ILSs	Connects to what they studied in the last lesson on Climate Change

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
		X	Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	He is supportive and guides them through the activity.
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	Teacher interacts freely with them, connects their activity to day to day life and creates a positive working climate.
	X		Students work individually from the beginning	Students start as a group and then individually or in pairs.
X			Students appear to be clear about the task	Teacher explains learning objectives clearly at the beginning of the lesson.
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	Some of the hands on equipment had minor issues.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	He makes sure all students participate, particularly those who appear to be uninterested.
X			Students doubts are managed effectively	
X			Students are familiar with ILS	They use apps & ILSs regularly with this teacher.
		X	Students seem to be motivated with the ILS	

Student behaviour

Y	N	NA	Measure	Notes
		X	Students are enthusiastic about the task (online ILS)	
X			Students are interested with the problem (specific ILS)	
	?		Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Two boys who seemed to have some behavioural issues were separated and paired up with other, more calm and engaged students. As the lesson progressed, one of them became engaged as well and advanced through the activities.
X			Students seem to be supportive during the activity	Some students who are more advanced go to help others who are progressing more slowly.

General comments
Major issues observed: An issue that appears constantly throughout these activities is the time management habits that the teacher has. Classroom management and good behavioral teaching practices, as a basis, are very important so that IBL can be applied and used with students.
Major outcomes observed: At the end of the lessons students seemed to have understood the major outcomes of what they had studied and they showed engagement in the combination of hands on activities and ILS.
Additional comments: None

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	27/05/2016
Name of teacher/	Mohamed Oubella
Years of experience in teaching	20
Main teaching subject(s)	Technology and ICT
Age(s) of students	All ages in secondary
Experience delivering lessons on ICT	Regular user of ILSs

Interview summary or transcription

Please describe your experience of Go-Lab so far

When did you first encounter it?

My first experience was 4 years ago.

What have you done with it … in particular writing ILSs, using ILSs, publishing ILSs?

I have created, used ILSs, published - a wide range of activities;

ILSs used in class or homework or project work or other modes of delivery?

I use it to teach and as a project;

How much support have you had?

I have used the tutorials online and by experience you take time to go back but I never asked someone to help me with it.

Any particular good or bad experiences?

Good experience: my level using ILS and Go-Lab has been increasing with the years (first year was focused more on discovering, I hadn't a real target to use it). These last times, I had a more specific target and as I was involved in these projects with you, I was also motivated to create a better product. I used ILSs but not often, so this time it motivated me more.

What are the best and worst aspects of Go-Lab in your experience?

Good aspects: it's a new way of teaching, like the flipped classroom, because students can work at home or in their own rhythm, they have access to the platform in their own time. Worst: when you don't have good internet connection, you have to find alternative solutions and some tools don't work when you use ILSs and when you want to use an existing ILS sometimes they are not complete so you have to adapt them and sometimes they only have the title. It takes a lot of time to find a specific topic. What could be done is to clean the repository of these kind of faulty ILSs.

Another good aspect: it's a new way, a new tool for teaching, for involving students and especially the ones who have a problem of concentration in classroom. These tools can help teachers to diversify his/her way of teaching and try to engage students more in the lesson. It takes time to know how to use GO-Lab, how to search the topics, how to create your own ILS but once you have done that, it's one of way of teaching to capture the attention of students. It mustn't be done all the time, it can be done in parallel with the normal lesson. Sometimes you have to time for assessment and to see if the students have all understood, so to go to the old way teaching. The ideal way is to combine the two ways of teaching.

Worst: if you have limited access to internet for uploading files, etc,

How effective are the learning outcomes from Go-Lab in your experience?

It's proved that using new ways of teaching improve the attention of students. They are more engaged and since I've been using Go-Lab and other tools, students are more attracted to using this kind of tools. For them it is like a game, but behind that there is a pedagogical methodology that is efficient.

Some students don't take time to understand the rules, the context and they just click next and wherever they want, especially when you have videos. But I think it's a characteristic of the new generation, but it doesn't happen all the time. For example, the last time you came, he (a student who was not very interested in the lesson) started participating when he saw the others working with Go-Lab.

Do the students enjoy learning in this way?

Yes. Some students are even proud to show their parents, and they feel important when I make them a contributor to the ILSs. Especially, this year, I take more time to use Go-Lab, more than one time per week.

Do you think other science teachers would have similar experiences? If not, why not?

In my school, I showed my colleagues the project and repository, but it's difficult to get them involved. As we have a reform in their curriculum, they are busy with a lot of things.

I showed them how to use it, and they said they will but I cannot check them all. So issues are: lack of time, barrier of language. The best way to involve teachers is from the very start with the new teachers in training. If it's done at least one hour per week or two weeks, I am sure they can learn it. There they have time to create and explore different ILS and so on.

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?

I'm leaving next year this school and the other teacher who uses Go-Lab, will leave as well. I hope the others will use it and I think they will if they have time, I'm sure at least one time they will use it.

Do you foresee any major obstacles to widespread adoption of Go-Lab for science teaching?

First: lack of time. The new programs and the new teacher generation have a lot to do. We must first disseminate at a large scale and to make some demonstrations with small groups. They must have their own laptop, use and create a simple ILS. And maybe someone who can talk to them about his experience (another teacher who uses Go-Lab easily). Ideally, it would be an official thing to do, so that they are obliged to do or semi-official. Maybe to contact the inspector of the topic/subject. If it's extracurricular, they are more reluctant. In France, we have a plan of training for teachers where they subscribe online and Go-lab could be there so it could be there in the plan of this training. And teachers go there and subscribe.

In France, a specific problem: we have a program and you must do it. For teachers to use other tools, they think it's time consuming: it takes too much time to use and discover the tool. They are reluctant.

You also have a lot of teachers who are stuck in their old ways of teaching, it's not easy to move them (like those who are approaching retirement).

HEAD OF SCHOOL INTERVIEW

Information box

General information	
Dates	27th May 2016
Name of Head of School	Eric Mégie
Years of experience in education	

Interview summary or transcription

What is your role within the organisation (or relationship with the organization)?

As a headmaster, I oversee all the National and European projects conducted by my teachers.

Have you used/heard of online laboratories before your Go-Lab experience?

I know the existence of Go-Lab through M. Oubella. He participated to various projects and contests proposed by EUN. He has taken part in Ingenious and Go-Lab projects, as well as in the Scientix project as a deputy ambassador

How would you characterize the implementation of IBSE in your school, before the Go-Lab experience? Familiarity with the concept and practice or not; Frequent/rare use

In ICT, technology and Biology the teachers were familiarized with ILS concept through their participation to a Comenius project. Their Estonian partners talked them about their experiences and practices. The outcomes were relevant for teachers and students.

The existence of the Go-Lab portal increased their interest and the implementation of IBSE especially in Technology.

How would you characterize your experience with the implementation of Go-Lab in your school? Positive/negative, useful/not useful and why?

The exchanges I had with the teachers concerned let me say that the impact is mixed. It takes time to convince colleagues to change their way teaching and adopt new methodologies such flipped classroom or ILS. Sometimes the barrier of language is a problem to overcome.

The Positive thing is that the implementation of Go-Lab open mind for new practices, methods and exchange between teachers all over Europe.

I found that M. oubella was acting rigorously, he bridged a gap between what Go-Lab was trying to achieve, and how STEM teachers must approach the concept.

Did Go-Lab have any impact on your understanding of inquiry based learning?

I personally have not used the portal Go-Lab but the experience of teachers who use it demonstrated to me that it is the case.

Did the teachers in your school find it easy to incorporate the use of Go-Lab in their curriculum? How many teachers have used it? What are their specialisms?

I have just two teachers who really incorporate the use of Go-Lab in their curriculum with the European class.

How would you characterise the impact of Go-Lab on the students? Why?

The impact was great for students. The implementation has been used in Comenius and eTwinning projects dealing with STEM, especially the eTwinning project called “Sound and Light Pollution”

How do you plan to use Go-Lab in the future?

Unfortunately, the two teachers involved in STEM projects will leave the school next year. I’ll do my best to convince other teachers to be involved in EUN projects.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

- During both observations the class was managed effectively, students participated and were supported equally, the small numbers of students also helped the class management.
- An issue that appears constantly throughout the observations was the time management habits that the teacher had. Classroom management and good behavioural teaching practices as a basis, are very important so that IBL can be properly applied and used with students (including the preparation of apps and computers before the lessons).

- The teacher insisted on the fact that even if it took him a time to know how to use Go-Lab, how to search topics and how to create his own ILS, it was a great teaching tool to involve students and capture their attention (especially with those who have concentration problems in the classroom).
- According to both teacher and head of school, using new modes of teaching improved the attention of students. “For them, it’s like a game but behind that there is a pedagogical methodology that is efficient”.
- It was difficult for the teacher to promote Go-Lab within his colleagues, they were not really keen on spending sufficient time to get involved. Mohamed believed further international and online trainings are needed in order for other colleagues to join and have the chance to explore and learn how to create ILSs.
- The existence of the Go-Lab portal has increased the interest of teachers and the implementation of IBSE especially in Technology. But still sometimes, the barrier of language is a problem to overcome.

4.2.3.3 Belgium (by Teodora Ioan, Enrique Martin)

DESCRIPTION

Title	WP8 - Case study
Country City/Region	Ostend, Belgium
Working language	English/Flemish (primarily)
Start/End Date	20/05/2016
Organizing Institute	EUN
Coordinator name and email	Teodora Ioan teodora.ioan@eun.org Enrique Martin enrique.martin@eun.org Evita Tasiopoulou evita.tasiopoulou@eun.org
Activity Form	In school activity
Activity Type	Implementation activity (WP8 Case study)
School profile	Ensorinstituut http://www.ensorinstituut.be/ Professional high school.
Total number of teachers/schools	1 teacher, 13 students
Implemented online labs	“Wet van Archimedes” http://graasp.eu/spaces/57a20dc63edb38aa877a3abe

Brief description	The implementation of the case study was organized within a predefined collection of qualitative and quantitative data, during the use of the Go-Lab ILS in a classroom, including: individual short teacher interviews per observation (pre and post), an observer sheet to be completed per observation, a final interview at the end of the second observation, a students' questionnaire and an interview with the Head of School. The items in students' questionnaire focused on students' attitudes and motivation towards STEM education.
Learning outcomes	Students were enthusiastic about the activity from the beginning, the fact that some of them were new to Go-Lab did not interrupt the normal functioning of the lesson. A seemingly more enjoyable and deeper learning process in which students get to "do" and hence better remember and understand the concept. Well proved example of a middle-low experienced Go-Lab teacher who was able to design a ILS and develop a lesson with no of external help whatsoever.
Photos or other relevant material	

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW

Information box

General information	
Dates	20/05/2016
Name of teacher/	Cindy Margodt
Years of experience in teaching	10
Main teaching subject(s)	Natural Sciences
Age(s) of students	12-16
Experience delivering lessons on ICT	Occasional user of computers and tablets during the lessons

Interview summary or transcription

<u>OBSERVATION 1</u>

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

My previous lessons have been about the concept of density and the subject chosen today is the Archimedes law, being a small part of the concept itself. I paved their way with a theoretical intro in order for them to be better understand today's exercise.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

I was previously involved in the Ingenius project, were they were also using inquiry based learning and had the chance to work with an ILS about Foucault's pendulum. I actually used it last year at my classroom, but the ILS was in English, so it was a little hard for students to follow the experiment. That is actually one of the reasons why I chose today's ILS, because it is in Dutch.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

I created my own, it is based on an existing one, but I modified everything and translated into Dutch. I took the lab, search for other videos in Dutch and modified it according to my needs.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

The students will have to play with the density options of the lab, changing mass and volume and observing what happens. Students can also see how the result changes depending on the materials applied.

I have actually asked a colleague to test the ILS at home and it took her 15 min to complete the exercise, I expect my students to be done with it in around 30 minutes.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

Some had used the pendulum experiment I previously mentioned last year, others have also tried a different ILS this year. But most of them are used to apps and computers, so I expect them to do fine.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

I think my students have understood what the main objectives were, but I have to say it was really hard to develop the exercise with tablets, screens were to small and students were not able to select and use the tools properly. Otherwise, the lesson went fine.

How did Go-Lab facilitate the achievement of these outcomes?

It was very useful because the subject of mass, volume and density had been discussed in advance. Now they were able to do it themselves and when they do it themselves, they can remember it better, they get to deeply understand the concept and this will definitely help them for the exams too.

How was the activity of the students? Did they work in groups? Did they collaborate?

At the beginning they were frustrated because the tablets were not working properly. But still they were really enthusiastic about using computers during the lesson and what's more, they have the possibility to repeat the exercise once home with the own computers and larger screens. Actually, in general we don't really use that much computers during our lessons because or lab is quite well sorted.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Cindy Margodt
Subject taught:	Natural Sciences
ILS (s) used:	De wet van Archimedes http://graasp.eu/spaces/57a20dc63edb38aa877a3abe
Observation date:	20/05/2016
Observation time:	9h30-10h30
Nr. of students present:	13

Please check the appropriate column for each item in a section, where:
1.) Y = The measure was observed
2.) N = The measure was not observed
3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	First students finished around 10h15
X			Instructor is well prepared for class (apps and computers prepared)	Everything is prepared in advance before the students come in (tablets, projector…)
X			Instructor appears to be confident to use the selected ILS	Initial explanation with clear answers to students, she knows her way around
X			Instructor uses a relevant ILS for the development of his classes	The teacher has been describing the concept of density during the previous lessons.

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
		X	Instructor switches from one phase to another (and goes back if needed)	
X			Instructor seems to be in control of all the phases of the ILS	All students go from phase to phase, doubts seem to be solved easily
X			Instructor connects the ILS to prior classes or ILSs	Prior lessons on density

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
		X	Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	The teacher doesn't seem to be doubtful when answering her students
		X	Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	All students seem to be happy about the activity
	X		Students work individually from the beginning	Working in pairs, one tablet per pair
X			Students appear to be clear about the task	After the initial explanation students start working independently
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	Tablets + explanation leaflet designed by the teacher

Student interaction

Y	N	NA	Measure	Notes
		X	Students are encouraged to participate	Students work independently
X			Students doubts are managed effectively	-
X			Students are familiar with ILS	Some of them had already used Go-lab last year
X			Students seem to be motivated with the ILS	-

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	Gradually losing interest as lesson progresses
X			Students are interested with the problem (specific ILS)	Especially at the beginning
		X	Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	
X			Students seem to be supportive during the activity	Students seem to be supportive one to another

General comments
Major issues observed: - Need of head phones (it was disturbing listening to all videos at the same time). - It was difficult for students to work with tablets, too small.
Major outcomes observed: None

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	20/05/2016
Name of teacher/	Cindy Margodt
Years of experience in teaching	10
Main teaching subject(s)	Natural Sciences
Age(s) of students	12-16
Experience delivering lessons on ICT	Occasional user of computers and tablets during the lessons

Interview summary or transcription

Please describe your experience of Go-Lab so far

I heard the first time of go-lab when I was in Ingenious. So I used the apps in the lessons last year, and this year too.

As for Go-Lab, I used an ILS of my own, about the density of mater and I also design my own ILS about skin cancer. I used it for the first time with students the other day in class. They loved it. Still, next time I will use computers instead of tablets.

In general, I would say I've had a good experience.

What are the best and worst aspects of Go-Lab in your experience?

Creating an ILS is hard, it is quite time demanding. But once you have it, it is nice to work with it. I believe the best practice when you combine the ILS with paper, otherwise you have to scroll up and down on a tablet and it doesn't seem very practical.

Also, most of the ILS aren't in Dutch and my students' English is not that good.

How effective are the learning outcomes from Go-Lab in your experience?

I believe it is especially useful when dealing with large student groups but also for a change in routine. Still, in my case, it is not that useful if it is not translated into your teaching language.

Some devices as tablets are not that functional, only maybe, with the use of paper to complement it. Otherwise with bigger screens it works way better.

On the other hand, my lab is quite well sorted, so I can do a lot of experiments in my class without using computers.

Do the students enjoy learning in this way?

They find it nice to work with computers. It was a pleasant welcome for them. I don't think they would enjoy it if they used it every week, but once in a while every trimester they really enjoy it.

Do you think other science teachers would have similar experiences? If not, why not?

Yes, actually my geography colleagues were really impressed with the ILS and the things you could do with it.

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?

My colleagues of geography a very interest and those from technology might be interested too.

The main advantage is that it is very handy for students, they can always use it and practice before they have to study for their exams.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

- The importance of the spillover effect in science education projects, how teachers previously involved in other projects are keen to participate in other future science projects and continue with their contribution to dissemination.
- Language continues to be an issue. The teacher mentions in several occasion the language barrier and ends up using only Dutch ILSs or translating them English ones into Dutch (time demanding).
- Without having much experience in the programme, the teacher has been able to modify and adapt ILSs to her needs easily.
- She also mentioned how she asked another colleague to check the ILS both for functioning and timing. This enhances collaboration and indirect dissemination.
- Many problems when working with tablets instead of laptops. Labs and apps are according to the teacher, not well designed for the screen's size on this kind of devices. Students also commented on the need of headphones during the ILS, otherwise it gets to noise when watching unsynchronized videos at the same time.
- When discussing the adoption of Go-Lab within her school it is mentioned a couple of times the possibility of using it for subjects such as of Geography and Technology. In this case the physical lab was 'quite well sorted' but it is not always the case, especially for other subjects.
- Better and deeper learning with Go-Lab: *"Now they were able to do it themselves and when they do it themselves, they can remember it better, they get to deeply understand the concept and this will definitely help them for the exams too".*

4.2.3.4 Cyprus (by Zacharias Zacharia, Tasos Hovardas, Nikoletta Xenofontos)

DESCRIPTION

Title	Implementation of three ILSs (WP8 Case study)
Country City/Region	Cyprus, Limassol
Working language	Greek
Start/End Date	14/04/2016
Organizing Institute	University of Cyprus
Coordinator name and email	Zacharias Zacharia zach@ucy.ac.cy Nikoletta Xenofontos xenofontos.nikoletta@ucy.ac.cy Tasos Hovardas hovardas@ucy.ac.cy

Activity Form	In school activity
Activity Type	Implementation activity (WP8 Case study)
School profile	Limassol Technical school is a public senior high school in Limassol, Cyprus. "Α Τεχνική Σχολή Λεμεσού": http://tech-scholi1-lem.schools.ac.cy/
Total number of teachers/schools	14 secondary students (16 years old, 13 boys and 1 girl)
Implemented online labs	Implementation of three ILSs: - Craters on Earth (familiarization) - http://graasp.eu/ils/565b54580fffcc3250f80341/?lang=el - Electrical circuits 1 (simple electric circuit and in series and parallel set up): http://graasp.eu/ils/570df6a2c3ddb608c844af64/?lang=el -Electrical circuits 2 (in depth investigation of the two types of set up, in series and in parallel): - http://graasp.eu/ils/570e0010c3ddb608c844af65/?lang=el
Brief description	The purpose of the implementation was the collection of qualitative and quantitative data, during the use of the Go-Lab in class, specifically interviews (pre and post) with the teacher, video recordings during the implementation activities and the completion of two students' questionnaires, before and after the implementation. The items in students' questionnaires focused on students' attitudes and motivation on STEM education. The first ILS was used for familiarization purposes. In this ILS, the Craters on Earth lab was used and students were guided, through the learning material, on how to design and execute experiments to collect data and address a research question. After students have learned how to use Go-Lab tools, they continued to the other two ILSs, which were focusing on electrical circuits and specific the simple electrical circuits and circuits connected in series and parallel. In these ILSs, the Electrical circuit lab and several apps (e.g. Hypothesis Scratchpad, EDT, Observation tool etc.) were intergraded.
Learning outcomes	Students seemed to enjoy the ILS about the Craters because it was something new and exciting for them. Later, when they worked on the two ILSs about the electrical circuits, they were interested to check their results in the light of what they had already been taught about the Ohm's law. Almost all students completed all the activities successfully. The goals of the implementation, as they had been set by the teacher, were achieved. Motivated students were more enthusiastic about the implementation, whereas students who less motivated about the nature of the activity, complained about the time needed to go through the ILS and the considerable number of tasks to be undertaken.
Photos or other relevant material	


BasicPlus
Beta
BasicPlus
Beta

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW

Information box

General information	
Dates	14/04/2016
Name of teacher/	Achileas Kapartzianis
Years of experience in teaching	20
Main teaching subject(s)	Physics
Age(s) of students	16-19
Experience delivering lessons on ICT	Involved in several projects on the use of ICT in education.

Interview summary or transcription

<u>OBSERVATION 1</u>

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

- Better and in depth understanding of the basic concepts related to electrical circuits (simple electrical circuit, in series and in parallel circuits, comparisons of the brightness of the bulbs and the electric current in series and in parallel circuits).

- The students have been taught the unit of the Electricity and they learned the Ohm's law. But they still have misconceptions concerning the concept of the electricity. That's the reason for the Go-Lab implementation with the ILS for the electrical circuits designed by UCY.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

- Participation in several programs concerning the implementation of ICT in school practice, such as the PROFILES, in which the teacher had implemented a learning environment about engineering by means of the STOCHASMOS platform.

- The teacher is a very motivated educator who follows all national efforts undertaken for the integration of ICT in school practice.

- In the current school year, the teacher is involved in two inquiry oriented educational projects, namely, Go-Lab, with the use of ILSs in his class, and PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education), with the implementation of multi-disciplinary Socio-Scientific Inquiry-Based Learning topics.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

The teacher contacted the UCY team and decided to use two ILSs on electrical circuits designed by the UCY team. After collaboration, minor changes were made and the focus of the two ILSs was on the simple electrical circuit, the circuits in series and in parallel, and the basic differences among the two types of setup.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

The implementation of the ILSs will last three didactic hours (approximately 40 minutes each) and each student will complete the lesson in a computer. For that purpose, the implementation will be carried out in one of the computer laboratories of the school.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

- The students had no experience with Go-Lab and inquiry learning.

- In previous lessons they had used several PASCO interfaces in order to take measures by means of several sensors.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

- Despite the technical problem with the browser at the beginning of the lesson, the implementation ran smoothly. Each student worked individually and completed the activities of the lessons in the time he/she needed to do so. This is an important thing for learning so that each student is able to achieve the learning goals set by the teacher. In contrast, in traditional teaching arrangements some students are not able to follow the flow of the activity sequence and at the end of the day they don't succeed in learning.

- By examining students' learning outcomes in the evening, the teacher realized that they completed all activities, despite the fact that their answers and learning products were not always very rich in content. This of course, is not a problem of Go-Lab, but instead, it is frequently encountered due to lack of scientific vocabulary.

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?

- The teacher was very well prepared to face any issues that might have emerged during the implementation, so everything was under control. The teacher's previous ICT experience helped in that direction.

- The familiarization activity with the Craters on Earth lab, helped very much, students were already familiarized with the Go-Lab learning environment.

How did Go-Lab facilitate the achievement of these outcomes?

The instructions, the labs and the tools that were used, helped students to perform the activities without many difficulties. However, students are used to take instructions by their teachers and the way they worked individually in the Go-Lab was something they felt that was very unusual.

What aspects of the lesson involved inquiry-based teaching and learning? How were the students learning?

- All inquiry phases were involved in the ILSs. At the beginning, the students had difficulties with hypothesis formulation. They didn't understand what a hypothesis is and they were asking for help, so that they could write down a correct statement. They didn't realize that a hypothesis can be true or false and the only way to know that is through experimentation. Some of them felt confident with this, but others were asking the teacher to provide them with a correct hypothesis.

- After the hypothesis formulation, the majority of the students had understood the process and they performed their experiments easily and quickly. Because students had a technical background, the phase of the experimentation, either as a hands-on activity or conducted in a virtual laboratory, was quite easy for them.

- In the Conclusion phase, the students were better in oral reasoning rather that in written. When they were asked to argue about their conclusion they were able to provide evidence from their data, but they couldn't express their reasoning as well in a written text.

How were you evaluating children's learning and how does this inform your planning?

The only negative aspect of the planning of the teacher was that the two ILSs were completed in the same day. This was done because the computer laboratory was not accessible at any time and day. At the end of the second ILSs, students felt rather tired.

How were you facilitating learning?

The teacher was trying to help students understand the process instead of giving them a correct reply to what they were asking, such as in the hypothesis formulation phase. In addition, the teacher helped students to overcome technical issues.

Is there anything else you would like to tell me about using inquiry-based science/mathematics?

- The design of the ILSs used was close to the guided inquiry model, this was a major reason for the successful implementation of the lesson. In contrast, the inquiry model that was followed in the previous year was closer to an open inquiry approach and the implementation wasn't so successful.

- It is important to gradually incorporate inquiry learning in the class, move from guided to less guided and then to open inquiry.

- The educational system in Cyprus doesn't promote the integration of inquiry learning in science. The main task is to prepare students for the exams without putting too much emphasis on the development of critical thinking.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Achileas Kapartzianis
Subject taught:	Physics
ILS (s) used:	The three ILSs used were in Greek language - Craters on Earth (familiarization): http://graasp.eu/ils/565b54580fffcc3250f80341/?lang=el - Electrical circuits 1 (simple electric circuit and in series and parallel set up): http://graasp.eu/ils/570df6a2c3ddb608c844af64/?lang=el -Electrical circuits 2 (in depth investigation of the two types of set up, in series and in parallel): http://graasp.eu/ils/570e0010c3ddb608c844af65/?lang=el
Observation date:	14/04/2016
Observation time:	9h20 – 12:00
Nr. of students present:	14 students (13 boys and 1 girl)

Please check the appropriate column for each item in a section, where:

1.) **Y = The measure was observed**
2.) **N = The measure was not observed**
3.) **NA = The measure was not applicable**

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	The teacher has reserved more time than the estimated timeline of the educational intervention, so that he would be able to react on any difficulty or problems that could emerge. Thus, time for undertaking learning activities with Go-Lab was sufficient.
	X		Instructor is well prepared for class (apps and computers prepared)	He didn't check the accessibility of the Go-Lab in the computer lab and at the beginning there was a problem with the internet browser (they had only IE and Mozilla). However, he found the solution very quickly by asking each student to download Google Chrome. This procedure took about ten minutes and then everything was ok.
X			Instructor appears to be confident to use the selected ILS	He knew the content very well. He was prepared for the students' difficulties (both technical and content specific).
X			Instructor uses a relevant ILS for the development of his classes	Yes the ILS was relevant.

Development

Y	N	NA	Measure	Notes
	X		Instructor uses the phases of the ILS consecutively	The lesson was designed to follow the phases of the inquiry cycle consequently. However, it was clear to students that they could have returned to any phase of the ILS at any time if they felt the needed to do so.
X			Instructor switches from one phase to another (and goes back if needed)	The teacher encouraged each individual student to go back to a phase anytime he detected that something was missing.
	X		Instructor seems to be in control of all the phases of the ILS	The instructor was able to diagnose difficulties encountered by students while undertaking learning activities and he was able to intervene timely and provide constructive feedback and support.
X			Instructor connects the ILS to prior classes or ILSs	The instructor was able to provide connection with previous lessons, especially, with lessons about the resistance of conductors and Ohm's law.

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	The instructor took ownership of the ILS he used
X			Instructor makes the ILS interesting to students	The instructor switched from individual work to whole-class discussions in order to problematize his students and elicit their curiosity.
X			Instructor responds to questions clearly and promptly	Teacher feedback was provided clearly and promptly.
X			Instructor uses appropriate and clear language	The instructor used proper terminology, which was intelligible by students.

Student introduction

Y	N	NA	Measure	Notes
		X	Students appear to be in a positive working climate before starting the ILS	
X			Students work individually from the beginning	Although students worked individually, communication among peers was encouraged by the teacher in several instances.
X			Students appear to be clear about the task	The majority of the students were on task. However, some students didn't pay enough attention on the instructions that appeared in the learning environment. Thus, they were asking for more guidance by the teacher himself or their more attentive peers.
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	A problem appeared in finding the proper internet browser, but that issue was solved in a few minutes.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	The instructor used questions to problematize students and orient them anytime they expressed any doubt
X			Students are familiar with ILS	The familiarization ILS at the beginning has proved very useful for that purpose.
X			Students seem to be motivated with the ILS	Although students were quite motivated, at the end of the implementation, some students expressed their negative feeling about the long duration, although they found the activities very interesting.

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	Some students were more motivated about the nature of the learning process, while others were not. However, at the end all students had completed the activities effectively.
X			Students are interested with the problem (specific ILS)	Concerning the ILS for the familiarization process (about craters), they seemed to like it because it was something new and exciting for them. Concerning the ILSs about the electrical circuits, the students were interested in checking their results in the light of what they had already been taught about the Ohm's law.
X			Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Each student worked on a computer. However, the communication and collaboration between them was encouraged by the teacher.
X			Students seem to be supportive during the activity	The teacher acted as a facilitator and moderator throughout the whole learning activity sequence.

General comments
Major issues observed: During the familiarization process the students were more disoriented because the learning environment of the Go-Lab was new to them. They had a lot of questions concerning the steps they had to follow. Later, during the completion of the activities of the two ILSs on the electrical circuits, they had become more confident about the procedure. However, they needed the approval of their teacher in every step they completed (e.g. hypothesis formulation, experiment execution, conclusion extraction). The time it took students to complete the three ILSs in a row was too long for them and that had caused to students a negative feeling, however they liked the way they had worked to learn more about the electrical circuits.
Major outcomes observed: Almost all students completed all the activities successfully. The goals of the implementation, as they had been set by the teacher, were achieved. The teacher had prepared very well the content of the ILSs and thus he was able to control the students' queries and demands.
Additional comments: The teacher is a very motivated individual who uses ICTs in his daily practice. He has a long standing experience with ICT innovations and inquiry learning. However, the students had no prior experience with inquiry learning and, thus, it was difficult for them to follow the inquiry cycle without having the approval of their teacher, about the correctness of every learning product they had created. In addition, they didn't pay the proper attention to the instructions in the learning environment, because they were not used to work without having the instructions given by their teacher.

TEACHER FINAL INTERVIEW

Information box

General information	
Date	14/04/2016
Name of teacher	Achilleas Kapartzianis
Years of experience in teaching	20
Main teaching subject(s)	Physics
Age(s) of students	16 – 19 years old
Experience delivering lessons on ICT	Involved in several projects on the use of ICT in education.

Interview summary or transcription

Please describe your experience of Go-Lab so far

- On September 2013 the teacher read the letter from the Ministry of Education that was send to every public primary and secondary school. He was interested in using ICT and inquiry in his teaching practice and Go-Lab proved to be the best way to do so.

- The teacher only used existing ILSs about electrical circuits because he didn't have enough time to create his owns, but he thinks that someone can easily learn how to create an ILS. He chose to implement ILSs about the electrical because they were in coherence with his instructional goals and the activities included in the ILSs were pedagogically correct. He expressed his willingness to use the Go-Lab in several other ways (e.g. creation of his own ILSs), but his personal liabilities and school's responsibilities are the main barriers to do so.

- He used existing ILSs for school activities.

- He had a very good support from the UCY team.

What are the best and worst aspects of Go-Lab in your experience?

<u>Creating ILS :</u>

Positive

- Despite the fact that he didn't create his own ILSs he thinks that it is very easy for someone to use Go-Lab the authoring tool. However, it is a common barrier that many teachers don't have enough time to spend in creating lessons with the new tool.

Negative

- Some online labs offer limited options for exploration. However, this is something that can be easily changed in collaboration with the labs' owners.

- If the Go-Lab project stops after the completion of the EU funding that will be a negative aspect. This is a very common trend with many other funded projects.

Using ILS and Classroom issues:

Positive

- Promotion of conceptual understanding of abstract concepts in science education, such as electricity, energy, force etc.

- Students improve their skills.

-There is enough compatibility with the curriculum (in the case of the electricity).

Negative

- Lack of special equipment and poor network connectivity in schools.

- The science teachers don't have the authority to use the computer laboratories whenever they want and this is a main reason for someone not to use Go-Lab.

Technology issues:

The negative aspects are not directly related with the use of Go-Lab itself but with technophobia at schools. Innovations, like one-to-one computing is being promoted, but schools are not investing money in buying new equipment to support such innovations.

Usability issues:

Positive

- The students were interested about the lessons and their interest was kept alive until the completion of all the activities in the ILSs.

Negative

- Go-Lab depends on the school's network connectivity and in many schools this is not good enough. However, this is a good opportunity for teachers to require better infrastructure in their schools, so that they would be able to use efficient innovations in their teaching practice, such as Go-Lab.

Learning issues:

Positive

- Go-Lab covers a broad range of topics in STEM education and it seems to serve as a very good paradigm for ICT integration in other learning subjects.

Inquiry based learning:

Positive

- Go-Lab promotes the use of inquiry learning and the understanding of scientific inquiry by students. It is very important for students to learn how real scientists work.

How effective are the learning outcomes from Go-Lab in your experience?

- Go-Lab is considered remarkable and the work done so far is rich and great. For the improvement of Go-Lab functionalities and usability, more funding is needed, however the work done so far meets the requirements of teachers.

- Suggestion for the creation of a national strategic planning for the adoption of Go-lab and the integration of its material in the Cypriot curriculum. Alongside, national experts committees can act as supporters for teachers, in order to utilize Go-Lab in their instruction effectively.

- Go-Lab has significant value in the understanding of abstract concepts in science. It also helps students study phenomena at the micro and macro level, ensuring their security and providing the appropriate equipment for each one without any additional cost.

- Go-Lab methodology prepares students for the modern labor market. It is not proper for schools not to be in alignment with the use of the technology investments in everyday life.

Do the students enjoy learning in this way?

The students enjoyed the activity with Go-lab. They concluded their investigations and compared their results with what they had learned in previous lessons about electricity and the Ohms' law.

Do you think other science teachers would have similar experiences? If not, why not?

Definitely.

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?

- The teacher will continue usuing Go-Lab.

- The Go-Lab can be used across all STEM subject domains.

- Only teachers that are interested in enriching their teaching practice will find Go-Lab useful, unfortunately, they are the minority (approximately 15%). The majority of science teachers in secondary education consider that they are quite competent in their instructional methods and they are not willing to change anything.

- At the beginning, the use of Go-Lab is time consuming, but a teacher can save time, in the midterm if he prepares good background material.

- Students are already familiar with technology and they can learn very quickly how to use new and innovative technology-based environments.

Do you foresee any major obstacles to widespread adoption of Go-Lab for science teaching?

- Inconsistency with the curriculum.

- Time for teachers to use such innovations in their schools, additional support and encouragement from school administrations.

- Teachers should collaborate in small groups, so as to make the use of such innovations easier and more productive.

- Lack of equipment and networking.

- The integration of inquiry learning is optional and, therefore, there is no motivation for teachers to use Go-Lab.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

- Almost all students completed all the activities successfully. The goals of the implementation, as they had been set by the teacher, were achieved. Motivated students were more enthusiastic about the implementation, whereas students who less motivated about the nature of the activity, complained about the time needed to go through the ILS and the considerable number of tasks to be undertaken.

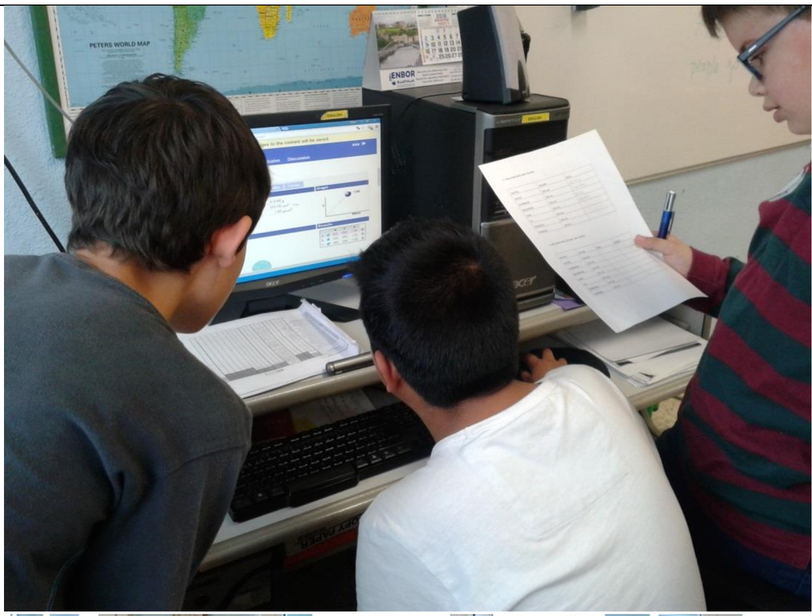
- Students liked a lab that had all its components ready to use, and infinite proving material. They liked it better than the real lab equipment. Also the fact that meters are accurate and easy to use and read.
- The instructions, the labs and the tools used, helped students to perform the activities without difficulties. However, students are used to receive further instructions from their teachers. Working individually in Go-Lab was somehow very unusual for them.
- In general, students were better in oral reasoning rather than written. When they were asked to argue about their conclusion they were able to provide evidence from their data, but they couldn't express their reasoning that efficiently in a written text.
- The educational system in Cyprus does not promote the integration of inquiry learning in science. As in the majority of educational systems it basically prepares students for the exams without putting too much emphasis on the development of critical thinking.
- The teacher used existing ILSs because he did not have enough time to create his owns, he did argue though, he believed it should be easy to learn to create one. It is a common barrier that many teachers do not have enough time to learn new classroom tools. *"At the beginning, the use of Go-Lab is time consuming, but a teacher can save time, in the midterm if he prepares good background material."*
- *"Negative aspects are not directly related with the use of Go-Lab itself but with technophobia at schools. Innovations, like one-to-one computing is being promoted, but schools are not investing money in buying new equipment to support such innovations".*

4.2.3.5 Spain I (by Javier García-Zubía, Almudena de la Peña, Isabel Ruiz)

DESCRIPTION

Title	Case Study in "Maestra Isabel Gallego Gorria" Primary School Teachers: Almudena de la Peña and Isabel Ruiz, and other three teachers.
Country City/Region	Spain/Basque Country
Working language	Spanish
Start/End Date	11th April 2016

Organizing Institute	Gallego Gorria Primary School
Coordinator name and email	Javier García-Zubía zubia@deusto.es Almudena de la Peña adelapenavaro@gmail.com Isabel Ruiz sabela61@gmail.com
Activity Form	Interview
Activity Type	Case Study
School profile	Public School "Master Isabel Gallego Gorria" is located in the neighbourhood of Iralabarri, Bilbao. Since 1995/96 the model D was entirely implemented. In order to achieve this, they work in small groups of teachers and parents of children. Thanks to these efforts, the school (that was about to disappeared) has continued to grow and become stronger. Now the C.E.P. "Gallego of Gorria" L.H.I. is the school of future. The age of students is between 6 and 12 years. Still, the IT needs to be strengthened. There is a limited number of computers and the internet broadband line quality should be improved in order to run contemporary technological teaching and learning tools.
Total number of teachers/schools	5 teachers in 1 school
Implemented online labs	http://graasp.eu/ils/571889ecc3ddb608c844b3c7/?lang=eu (remote lab) (Almudena de la Peña) http://graasp.eu/ils/5724f10dc3ddb608c844b758/?lang=eu (virtual lab) (Almudena de la Peña) Archimedes remote lab: http://www.golabz.eu/lab/archimedes-principle Splash virtual lab: http://www.golabz.eu/lab/splash-virtual-buoyancy-laboratory http://graasp.eu/ils/56bcb8b15829e7041c0ff9ab/?lang=en (Isabel Ruiz)
Brief description	Almudena designed the ILS to explain the Archimedes Principle and water displacement in the Archimedes experiment. Two out of 5 participating teachers where interviewed (the person responsible for IT department as well as the secretary of school were interviewed during this case study too).
Learning outcomes	Density in terms of mass and volume. Water displacement when an object is left it into the water. Water displacement depending on the object sinking or floating. Differences between a virtual and a remote lab.
Photos or other relevant material	Audio files of recorded interviews : https://goo.gl/93Gzed

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW (Observation 1)

Information box

General information	
Dates	11/04/2016
Name of teacher/	Isabel Ruiz
Years of experience in teaching	33
Main teaching subject(s)	English in Primary School
Age(s) of students	11-12 years old
Experience delivering lessons on ICT	No prior experience

Interview summary or transcription

OBSERVATION 1

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

We have two different objectives: one is to learn the basis of the Archimedes Principle, and the second is to practice English. Keep in mind that I am a teacher of English. So I have tried to use the ILS to teach also English.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

No. I am not an expert on ICT in the classroom either. I guess this will my biggest problem with the ILS, but only at the beginning of the experience.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

As you know, I was "invited" by Almudena to join the Go-Lab project. I went to the training organized by Berritzegune at the University of Deusto. Finally, I copied the ILS made by Almudena, I translated into English and I also adapted it to my needs.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

First, I need to know how the experience is working. Remember that in my classroom I have to mix English and the ILS. My idea is to work 2 or 3 sessions with ILS and the Archimedes Principle.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

For them it is the first time with ILS and Go-Lab.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

It has been very good. I was worried because this group of students speaks a lot during the lessons. Also, because in my classroom, they are used to work individually, so the sessions were a challenge for them, and for me.

Actually the group work was OK and they were even more concentrated during the activity. It seems that Go-Lab helped them to be more centred and comfortable during the session.

I worked with groups individually, therefore, one group was working with the ILS, and the rest of the groups were working with other tasks.

My main objective is English, so for me it has been fifty-fifty.

Not all of the students have had the same results, but they were all very interested.

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?

Yes, more or less (see the following answer).

How was the activity of the students? Did they work in groups? Did they collaborate among them?

At the beginning, I gave students a general presentation to introduce the concepts, the vocabulary, and so on. After this, the students in groups, had to write the hypothesis, make the experiments, etc.

We still have one last session to discuss the whole experience with the ILS.

How did you integrate the inquiry in the activity? How the students understood the activity and the inquiry?

I would like to check the results once the last session takes place in order to see if students understood - at least in a basic level - the inquiry, scientific method, etc. But at this moment I would be able to judge their understanding.

The methodology has been important. In the classical way, I would have taught the contents in the blackboard (definition, formulas…), but using this approach, students have discovered by themselves all concepts.

I want to remark that during this sessions, the students have been involved in different experiences (what we call "corners") and for them, the ILS has been the most interesting "corner".

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Isabel Ruiz
Subject taught:	English in Primary School
ILS (s) used:	Archimedes I: Floatability using a remote lab http://www.golabz.eu/spaces/archimedes-i-floatability-using-remote-lab Archimedes principle II: Water displacement http://www.golabz.eu/spaces/archimedes-principle-ii-water-displacement
Observation date:	11/04/2016
Observation time:	
Nr. of students present:	

Please check the appropriate column for each item in a section, where:

1.) **Y = The measure was observed**
2.) **N = The measure was not observed**
3.) **NA = The measure was not applicable**

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	
	X		Instructor is well prepared for class (apps and computers prepared)	
X			Instructor appears to be confident to use the selected ILS	
X			Instructor uses a relevant ILS for the development of his classes	

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
X			Instructor switches from one phase to another (and goes back if needed)	
X			Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
	X		Students work individually from the beginning	
X			Students appear to be clear about the task	
	X		Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	
	X		Students are familiar with ILS	
X			Students seem to be motivated with the ILS	

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	
X			Students are interested with the problem (specific ILS)	
	X		Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	
X			Students seem to be supportive during the activity	

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW (Observation 2)

Information box

General information	
Dates	9/06/2016
Name of teacher/	Almudena de la Peña
Years of experience in teaching	33
Main teaching subject(s)	General Primary School
Age(s) of students	11-12 years old
Experience delivering lessons on ICT	Regular user of ILSs

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

Remember that we are working with students of primary school, so they have different levels and objectives. In this regard, I have two main objectives:

- Content. They will work with the Archimedes Principle and with water displacement.
- Activity. They will be "scientists", trying to use scientific methods, make experiments, and analysing the results of the experiment.

What is your (the teacher's) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

I generally use IT in my classroom. Also I am the IT responsible for the school.

In this sense, my students are comfortable with the use of IT in the classroom: digital blackboard, tablets, etc.

This is my first contact with Inquiry based learning though. At the beginning I thought that it was going to be impossible to apply this approach (and technology) within students of a primary school, but it is possible. It was hard because my scientific level is not high (it is actually very low), so I am learning at the same time that I am creating and teaching.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

I have worked with several ILSs, but I haven't created one from scratch, what I have done is coping and adapting an ILS designed by Javier. I adapted it and also split it in two different ILSs: one using a remote lab (Archimedes Lab in Deusto) and another using a virtual lab (Splash).

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

First, I will present the ILS and the activity to the students and then I will divide the classroom in groups. I think that we will need two sessions of 45 minutes to complete the activity, and after this one more session for the conclusions, etc. In total, I around 3-4 sessions.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

This is their first time with Go-Lab.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

As usual, slower than I expected, but that is normal.

It is early to say if students have reached their objectives, they are following the implemented method in the ILS, but they still need more time to finish the activity.

Did you use Go-Lab as you had intended to? Where there any deviations from your planning?

Yes, I followed the steps.

How did students behave? Did they work in groups? Did they collaborate?

Yes, they worked in groups. In our school we share the IT equipment and remember that they are very young; they need to work together.

How did you integrate the inquiry in the activity? Did the students understand both the activity and the inquiry?

I have been in several training meetings at the University of Deusto and I have used the ILS produced by Javier, so I think that the Inquiry was properly integrated.

In primary school the students do not distinguish what the inquiry is, the teacher is in charge of this. But they know what a question is, and what an answer is. I think that the students liked the ILS, they were interested in the activity.

In order to see if the objectives have been reached, I have to wait and see the final results produced by the students: posters and presentations.

Likewise, in collaboration with Javier, I gave the students a pre-test and after the experience will hand them a post-test. Finally, all this information will be processed by the University of Deusto team. I have to wait.

I have used two labs in the classroom: a virtual lab and a remote lab. In my opinion, the students have been more comfortable with Splash, I believe it is more intuitive and easy to use.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Almudena de la Peña
Subject taught:	General primary school
ILS (s) used:	Archimedes I: Floatability using a remote lab http://www.golabz.eu/spaces/archimedes-i-floatability-using-remote-lab Archimedes principle II: Water displacement: http://www.golabz.eu/spaces/archimedes-principle-ii-water-displacement
Observation date:	9/06/2016
Observation time:	
Nr. of students present:	

Please check the appropriate column for each item in a section, where:
1.) Y = The measure was observed
2.) N = The measure was not observed
3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	
	X		Instructor is well prepared for class (apps and computers prepared)	
X			Instructor appears to be confident to use the selected ILS	
X			Instructor uses a relevant ILS for the development of his classes	

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
X			Instructor switches from one phase to another (and goes back if needed)	
X			Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
	X		Students work individually from the beginning	
X			Students appear to be clear about the task	
	X		Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	
	X		Students are familiar with ILS	
X			Students seem to be motivated with the ILS	

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	
X			Students are interested with the problem (specific ILS)	
	X		Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	
X			Students seem to be supportive during the activity	

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	11/04/2016
Name of teacher/	Isabel Ruiz
Years of experience in teaching	33
Main teaching subject(s)	English in Primary School
Age(s) of students	11-12 years old
Experience delivering lessons on ICT	

Interview summary or transcription

Please describe your experience of Go-Lab so far

For us the experience has been very good, but it is very important to adequate the level of the ILS and the level of challenges to the students. We feel that the Go-Lab is more oriented to secondary or high school levels, so in primary we need to keep the feet on the ground.

Sometimes the teachers try to create a “better” ILS or a more complex one... For us it is very important to fix an adequate level for the ILS and for the challenges.

Initially I thought that Go-Lab could only work for secondary schools, but during training provided we discovered that the tools could be applied in primary schools too.

What are the best and worst aspects of Go-Lab in your experience?

I agree with Almudena, for me the most important feature is the methodology - the inquiry based learning. It is very exciting to have a guide to teach science and of course, the labs are also very important to implement the strategy, to have something to show. Still, I believe inquiry was the best part of my experience.

The use of apps like Hypothesis tool was also very important and succesful. They help a teacher organizing the inquiry around easy tools. As for the worst, I do not know.

Do the students enjoy learning in this way?

Yes, Go-Lab is very helpful for the students. They have enjoyed the activity and other teachers are using or planning to use the same ILS in their classrooms. So we think that the experience is suitable for our students.

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	9/06/2016
Name of teacher/	Almudena de la Peña
Years of experience in teaching	33
Main teaching subject(s)	General Primary School
Age(s) of students	11-12 years old
Experience delivering lessons on ICT	

Interview summary or transcription

Please describe your experience of Go-Lab so far

I was introduced to the Go-Lab project two years ago on a meeting in the University of Deusto. It was organized by the UDeusto and the Berritzegune (Innovation Dpt. Of the Education Dpt. Of the Regional Government) to introduce us in the project.

Later on, I attended a specific workshop on design and implementation of ILS. In 2015-2016 school year I designed and implemented an ILS for the Archimedes Principle. I decided that Go-Lab was a good idea in order to develop science in my school. Finally, I ended up involving 5 teachers in primary level in my school. We are still in the process of applying the ILSs, so we need more time to see the results.

What are the best and worst aspects of Go-Lab in your experience?

The best is the inquiry, the use of the inquiry in science. It was a surprised myself how much it helped me. I especially like the apps and the hypothesis tool is very useful for both teachers and students. As for the worst, I do not know.

Do you think other science teachers would have similar experiences? If not, why not?

I recommend the teachers to use the ILS even in primary school. From the very beginning, UDeusto team accepted the challenge of using ILS in the primary level.

As I have said, I believe in the Go-Lab project, and I am trying to involve more teachers in my school. For example, the English teacher is going to use the ILS of the Archimedes Principle to teach English using science vocabulary and the Go-Lab platform as a IT tool. We will see the results.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

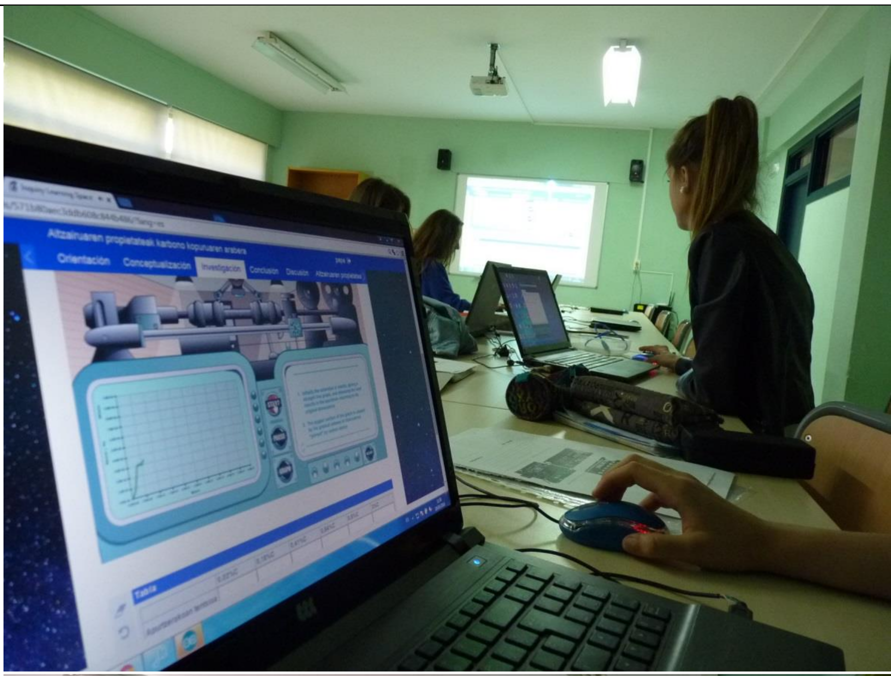
- This ILSs have been different from the other conducted so far for two main reason: they were meant for primary student and they were also used as part of the English lessons.
- It is argued by both teachers that Go-Lab seemed to help students to be more concentrated and comfortable during the lesson. This together with the fact that students were working by groups, allowed the teachers to go task by task no matter the timing with all students.
- "The methodology has been important. In the classical way, I would have taught the contents in the blackboard (definition, formulas…), but using this approach, students have discovered by themselves all concepts."
- Teachers argue that due to the young age of students it was better for them to work in groups sharing the IT equipment.
- According to both, their approach to IBL was the best part of their experience, even though they admit that virtual labs and apps are important too, in order for them to be able to implement their strategy.

4.2.3.6 Spain II (by Javier García-Zubía, Andeka Zubiaur, Arantzazu Latorre)

DESCRIPTION

Title	Case Study at Aixerrota Secondary School
Country City/Region	Spain/Basque Country
Working language	Spanish
Start/End Date	26-27 May 2016
Organizing Institute	University of Deusto and Aixerrota Secondary School

Coordinator name and email	Javier García-Zubía zubia@deusto.es Andeka Zubiaur irzubiaur@aixerrotabhi.eu Arantzazu Latorre
Activity Form	Interview
Activity Type	Case Study
School profile	Aixerrota school was created by the junction of two schools, the secondary school Getxo 3, launched in 1979, and the Vocational Training Institute: CP Aixerrota, created in 1983. Aixerrota school (BHI) was developed as a new model of Basque schools in 1998, studying the ESO, Baccalaureate and vocational training today. Aixerrota BHI is located in Getxo, Andra Mari, in the Bay of Biscay. The age of students goes from 12-18 (secondary school), to 18-20 (professional development). The school has participated in local/ regional projects such as Agenda 21or ICT within others. They have a very well developed IT infrastructure that supports teaching and learning technological approach. http://www.aixerrota.hezkuntza.net/
Total number of teachers/schools	1 teacher in 1 school
Implemented online labs	Tensile testing. UK Centre for materials education Lab: http://classroom.materials.ac.uk/tensile.php http://graasp.eu/ils/56cec3835829e7041c1004fa/?lang=es
Brief description	Andeka Zubiaur designed an ILS to show to the students the influence of the carbon in the steel: tensile testing.
Learning outcomes	Effect of the concentration of carbon in the properties of the steel.
Photos or other relevant material	Audio files you can find on https://goo.gl/hoMhvi


Altzairuaren propietateak karbono kopuruaren arabera
Orientación
Conceptualización
Investigación
Conclusión
Discusión
Tabla

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW

Information box

General information	
Dates	26-27/04/2016
Name of teacher/	Andeka Zubiaur Soto
Years of experience in teaching	
Main teaching subject(s)	Industrial Technology
Age(s) of students	16-17 years old
Experience delivering lessons on ICT	Experienced user

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

I am teaching Industrial Technology and one of the chapters of the subject is “steel”. Steel characteristics depend on the carbon added to iron during its fabrication. Interestingly,the amount of carbon should not be high, but neither very low. This means there is a clear opportunity for inquiry and experimentation.

What is your (the teacher’s) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

I have a long experience using IT in education: Moodle, simulators, google drive, PhET laboratories, etc. I usually integrate them during the lessons; and my students like them.

But this is my first time using a “serious” inquiry approach. Of course, everything was clear for me, but it is very important to have an integrated approach of the inquiry learning, and not having a mix of tools that depend on the teacher.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

I started from scratch to design my own new ILS, I followed a strict inquiry process, using the five phases of the ILS.

Last year I designed another ILS, in this regard, it has been easy to design a new one using the new features of graasp. Now the Go-Lab graasp platform is easier to use and more powerful. Since I had a prior experience and the tool has been improved, in my opinion, the result has been better.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

In this ocassion, I decided to work with the students in the computers room. All work will be done by students with my support. I decided to do this because I am not sure if the process is going to be good or not, and I would like to see the real problems in front of me. I will help students; and at the same time, I will see how to improve the ILS for the next year.

The use of the ILS will be individual, and after performance of the ILS, the students will upload a file with some questions and activities. This file will be uploaded in Google Classroom.

I decided to uses Google Classroom because last year I had some problems, especially with the nicknames of my students, and so on... So, the material for activity evaluation of the students will be managed out of the ILS, in my own repository.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

This is the first contact of my students with Go-Lab. But before the activity I explained them what the Go-Lab project is.

The students use to apply different technologies for the learning process. This school has a high score attending to its technological resources, so our students are very comfortable with these kind of tools.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

In general everything went fine, the activity was clear and the tools worked perfectly. Also the time given to the students was correct (all of them finished their work more or less on time). Now they have to work with the obtained data.

Do you think that the students have reached their objectives?

Yes, all of them understood the concept of the carbon effect in steel and experimented with carbon and steel using the virtual lab.

Did you use the ILS as you expected?

Yes, everything was fine; I did not have mayor issues.

How was the activity of the students? Did they work in groups? Did they collaborate?

The activity was individual, so there was no interaction among the students. Even the final task (the report file) has to be done individually.

How did you integrate the inquiry in the activity? How the students understood the activity and the inquiry?

The inquiry was mostly concentrated in conceptualization and experimentation.

During the conceptualization phase they had to write some hypotheses, and this was not that easy for them. Students wanted to write hypothesis that were true from the very beginning, they wanted to be sure that at the end the answer was going to be correct.

It was hard for them to understand that a hypothesis is not true or false from the very beginning. The experimentation phase helped the students to solve these hypotheses.

During the activity I explained them the scientific method, and at the end they “aligned” hypos-experiment-answers, so from my view point, they improve their scientific reasoning, even in this very simple scenario.

As for the experimentation phase, students discovered that not all the amounts of carbon were correct to make steel, they added different amounts of carbon and experimented how the behaviour of steel changed. At the end, they understood the overall process.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Andeka Zubiaur Soto
Subject taught:	Industrial Technology
ILS (s) used:	“Altzairuaren propietateak karbono kopuruaren arabera”. Characteristis of Steel. http://graasp.eu/ils/571b80aec3ddb608c844b486/?lang=es
Observation date:	26-27/04/2016
Observation time:	Group A: 26-27 9.25-10.20 and 8.30-9.25 Group B: 26-27 may 13.35-14.40 and 12.40-13.35
Nr. of students present:	Group A: 19 students, Group B: 13 students,

Please check the appropriate column for each item in a section, where:
1.) Y = The measure was observed
2.) N = The measure was not observed
3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	
X			Instructor is well prepared for class (apps and computers prepared)	
X			Instructor appears to be confident to use the selected ILS	
X			Instructor uses a relevant ILS for the development of his classes	

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
X			Instructor switches from one phase to another (and goes back if needed)	
X			Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
X			Students work individually from the beginning	
	X		Students appear to be clear about the task	
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	
	X		Students are familiar with ILS	
X			Students seem to be motivated with the ILS	

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	
X			Students are interested with the problem (specific ILS)	
		X	Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	
X			Students seem to be supportive during the activity	

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	26-27/04/2016
Name of teacher/	Andeka Zubiaur Soto
Years of experience in teaching	
Main teaching subject(s)	Industrial Technology
Age(s) of students	16-17 years old
Experience delivering lessons on ICT	Experienced user

Interview summary or transcription

Please describe your experience of Go-Lab so far

I have known the Go-Lab project for two years. The first time, I heard about it was during a workshop at the University of Deusto. It was organized by UDeusto and the Berritzegune (Innovation Department of the Education Department of the Regional /Basque Government) to introduce us to the project.

After this, I went to an specific workshop about the design and implemention of ILSs. In 2014-2015 I designed and implemented the ILS called Palancas (Lever), it was written in Euskara and Spanish. I appreciated the results and I decided to repeat this year.

In 2015-2016 UDeusto and Berritzegune organized a professional development workshop. The participants of this workshop were granted with a certificate of the Basque Government. We had 15 hours “work in class” to discover Go-Lab and design an ILS using the Go-Lab labs and apps. In this ocassion, I designed the ILS called “Influencia de la cantidad de carbono en las propiedades del acero" (Influence of carbon in the characteristics of steel). I implemented it in the classroom with Udeusto's help.

What are the best and worst aspects of Go-Lab in your experience?

Best Aspects:

- Go-Lab offers a great amount of online labs and I do not need to search them, they are already classified in golabz. But Go-Lab is not only labs, it is also apps. You can use apps to reinforce students learning process. Used in a correct way, students will obtain a higher impact with a smaller effort. This improves their capacity of learning.

- As the ILS is created in graasp, it can be offered to the students through Internet, giving students the posibility to also access the activities at home. In this way, parents get to know this innovative tools and because the effort of schools and teachers can be observed and appreciated by the parents.

- In our region, the regional government classifies schools based on the level of integration of IT in the learning process. In this regard, Go-Lab helps the school to increase its level.

- Since I trust Go-Lab, I can use the same ILS next year, or even use the ILS designed by other teachers in other countries.

Worst Aspects:

- Sometimes the apps integrated in graasp seemed not to work properly and the problem was not in the quality of the Internet connection. It is frustrating to design something, and see during the implementation that it is not running as it should.

- I decided not use the File Upload app because I had problems with it in past. Since then I do not feel confident with the app.

- Students need to use a nickname, but I was not sure if I was going to be able to recognize each student.

- I would like to have more control over results of my students.

Do the students enjoy learning in this way?

It was interesting, because it was a different way of learning for them which included the use of computers, so it was fun from the beginning. This is important, but at the same time it was also a problem. The students did not have the feeling they were making science, real science; they felt they were playing.

Do you think other science teachers would have similar experiences? If not, why not?

I recommend teachers to use the ILS, even without knowing how to design one. Using ILSs teachers can change their way of her teaching, and can give students the opportunity of discovering by themselves certain effects and laws (inquiry).

In my school other teachers are interested, but at the end they do not have a time (or real desire).

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?

During next year I will use again the designed ILS. Since the IT office has info about Go-Lab and the ILSs, they will disseminate this teaching instrument amongst the other teachers. It is important to mention that our school wants to remain in the top level of IT integration.

To disseminate Go-Lab, it would be interesting to apply the inquiry approach to the technological subjects too. I understand that the inquiry is more for science, but maybe something similar could be done for technology: electronics design, robots, etc.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

- Go-Lab tools have been proved to be equally useful for the development of technology lessons. The teacher seems to be truly satisfied with the results.
- According to the teacher the Graasp platform is now *"easier to use and more powerful".* Since he was involved in the programme from the first year, he has been able to experience the improvement of different tools. Still, he doesn't use Graasp to upload results, he comments on several issues in this regard, especially when it comes to student nicknames.
- In this case the teacher asked students to work individually from beginning to end. There zero interaction between them during the whole process.
- This teacher is an experienced Go-Lab (and in general technology-enhanced learning environments) user. He attended 2 workshops organized by Udeusto and masters the creation of ILSs and the use of labs and apps.
- It is also mentioned as a positive aspect the fact that the tool is offered through the internet and can be accessed at home. Is this regard, the teacher highlights that in this way parents are more aware of the efforts the school is making in using innovative tools with their students.
- The teacher also commented on the dual component of using virtual labs: *"The students did not have the feeling they were making science, real science; they felt they were playing".*

4.2.3.7 Spain III – Instructors Interview (by Javier García-Zubía, Andeka Zubiaur, Arantzazu Latorre)

DESCRIPTION

Title	Interview with CESIRE instructors
Country City/Region	Spain/Catalonia (Barcelona)
Working language	Spanish
Start/End Date	9 June, 2016

Organizing Institute	CESIRE: http://xtec.gencat.cat/ca/innovacio/cesire/ Fundació Catalana per a la Recerca i la Innovació (FCRi): http://www.fundaciorecerca.cat/en/
Coordinator name and email	Jordi Regales. jregales@xtec.cat Javier García-Zubía, zubia@deusto.es
Activity Form	Interview
Activity Type	Discussion
School profile	CESIRE is the Office for Innovation in Education of the Education Department of the Catalonian Regional Government. Its main objective is to promote educational innovation in primary and secondary schools.
Total number of teachers/schools	4 CESIRE instructors and the manager of the “Fundació Catalana per a la Recerca i la Innovació”. Instructors: Jordi Regales, Secondary School Technology Teacher. Fina Guitart, Secondary School Physics and Chemistry Teacher. Silvia Lope, Secondary School Biology and Geology Teacher. Rosana Fernández, Secondary School Technology Teacher. David Segarra, FCRI
Implemented online labs	N/A
Brief description	Before the summative workshop held in Barcelona in 9th June, UD team (Javier Garsí-Zubía & Olga Dziabenko) interviewed the instructors of CESIRE. Its main objective is to promote innovation in educational, both in primary and secondary schools, while promoting research in education.. CESIRE consists of 15-20 instructors plus the board of directors. In this interview we spoke with: Jordi Regales, Fina Guitart, Silvia Lope and Rosana Fernández. Also present during the interview was David Segarra Mediavilla, Manager of the Action Research Program "Science and classroom". He is involved in different projects and dissemination activities. Fundación Catalana is a private organization supported by companies and businesses. It organizes more than 70 educational activities per year, and around 1000 teachers attend these activities. The discussion was centred on Go-Lab experience in CESIRE daily work, and the sustainability of the Go-Lab project. This interview is a summary of the answers and is presented as unified opinion.
Learning outcomes	N/A
Photos or other relevant material	Video link: https://goo.gl/FiwCFC

INSTRUCTORS INTERVIEW

Information box

General information	
Name of instructors	Jordi Regales Fina Guitart Silvia Lope Rosana Fernández David Segarra
Organizations	CESIRE FCRi
Date	09/06/2016
Duration of the interview	2h

Interview summary or transcription

What is your role in your organization?

CESIRE (C): We are instructors to support different educational resources and actions offered by the CESIRE.

Foundation (F): I organize different kind of activities for the FCRi.

Have you ever used a remote or virtual lab?

C: Yes, we have promoted the use of virtual labs in education. We know the offer of PhET, Explorescience, etc. We have also used remote labs. Some years ago we started a collaboration with Francesc Garofano, Ramon Bragos and UPC[3] to access different remote labs in electronics, Hook's Law, etc. Unfortunately, now it is not running anymore.

Before Go-Lab, did you use the inquiry approach in the classrooms?

C: Yes, we have organized inquiry workshops.

F: Yes, we are promoting this approach in the classroom in order to reach good science. We appreciate indeed the methodology of inquiry learning.

How was your experience with Go-Lab?

C: Very good. We have disseminated the Go-Lab project in our network and we have also organized, in collaboration with University of Deusto, different workshops about the use of the Go-Lab resources. Furthermore, we have also used the Go-Lab tools in the Master of Didactics for Chemistry.

Has the Go-Lab experience helped you to better understand the inquiry based learning?

C: Yes.

[3] http://ilabrs.upc.edu/ca/documentacio

Do you think that Go-Lab increases the motivation for the use inquiry methods and the online labs?

C: Yes, of course. Not only it promotes the use and understanding of inquiry learning, but also the use of tools (apps) supporting these methodologies. For us, the most important part of Go-Lab is the inquiry itself, but it is also important to have proper labs and tools.

Do you think it is difficult to integrate Go-Lab in the classroom?

C: It depends on the teachers. Some of them are very active implementing projects like Go-Lab.

Do you plan to continue using Go-Lab in the future?

C: Yes of course. We are interested on specific training, and we have several areas on this field of activity.

F: Yes, it is the key for the future: inquiry + online labs.

The following ideas were also mentioned during interview in relation to teachers' experiences with inquiry learning *(although not directly connected to the questions)*:

Some teachers only attend to the curricula of the subject. What's more, they use text books as main reference for the subject, without analyzing what is it they have to teach. In this regard, the School "Jesuitas" has developed an analysis concluding that at least the 20% of the curricula is not interesting from a science education point of view.

Some teachers do not like to use Go-Lab (or other similar technologies) because they are not comfortable with IT tools, they have the feeling that students might more experienced than them, especially with IT tools: computers, interfaces, webs, and so on.

Some teachers are very active and participate in most workshops offered by CESIRE. In this case, one project is substituting a previous one... It is important to be in control of this process. For example, in Barcelona there are 150 registered institutions offering training in education and all of them have official recognition.

At the beginning, the use of Go-Lab (or similar technologies) can slower down the teaching process, but after one or two years it becomes faster and more interesting. For this reason, the objective of CESIRE is not only to promote them, but also to sustain them.

As for the labs:

One of the tasks of the CESIRE is to provide the schools with experimental equipment. If a school needs to develop a biological experiment with fishes or with microscopes, teachers ask CESIRE to support this activity. CESIRE has a large repository of experiments to be shared with schools and teachers and for this reason, they are also very interested in remote labs, because they can have direct access to online labs without having to ask for CESIRE's facilities.

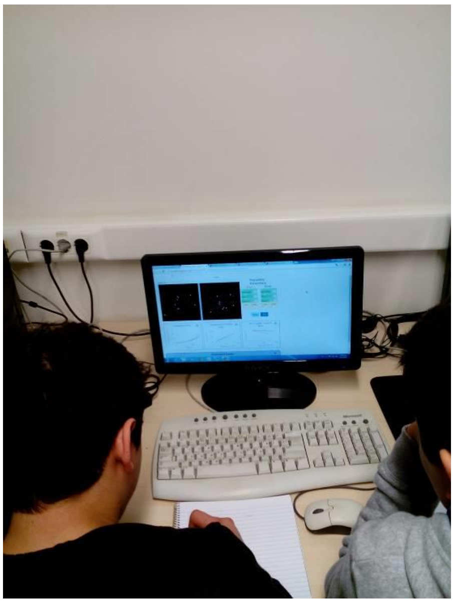
Teachers as well as the CESIRE people need training, not only for the design of ILSs, but also for their use.

In relation to primary education, it was also mentioned that online labs are for the moment not that interesting, since they are not designed for these ages. But it definitely would be interesting to develop online labs for primary students, keeping in mind that at this age student still have not developed their abstract thinking.

4.2.3.8 *Greece – Instructors Interview (by Panagiota Argyri)*

DESCRIPTION

Title	Implementation ILS from GOLAB repository
Country City/Region	Greece
Working language	Greek
Start/End Date	10/03/2016
Organizing Institute	EA
Coordinator name and email	Panagiota Argyri, argiry@gmai.com
Activity Form	In school activity
Activity Type	Implementation activity (WP8 Case study)
School Profile	B1 Class Model High School Evangeliki of Smyrna • Promotion of educational research in practice, in cooperation with the Departments of Universities, in teaching of individual subjects. • Training for students of University. Experimental implementation in particular: - PROGRAMMES studies, curriculum and teaching methods, - Any kind of Educational material of any kind, - Innovations teaching practices, - Innovations and creative activities, - Evaluation of programs of quality of educational work.
Total number of teachers/schools	1 teacher, 27 students
Implemented online labs	*http://graasp.eu/ils/54cbab42479265d7425bf788/?lang=el* *http://padlet.com/argiry/1u1eei6psenr* *http://padlet.com/argiry/593ok9iw4xx8* *http://padlet.com/argiry/rjca2pgarwkt* *https://docs.google.com/forms/d/1Vn8dnz_LNwkzOqgrZ2Udu2LaR8J0WIvu5A_gN3BxwWk/viewform?usp=send_form* *http://virtualbiologylab.org/NetWebHTML_FilesJan2016/LogisticGrowthModel.html* *http://virtualbiologylab.org/Models/Model_LogisticGrowth.html*

<table>
<tr><td>Brief Description</td><td>Inquiry learning process:
- Knowledge in mathematics predictive models of increasing population size;
- Exponential and accounting math and parameters (variables) influencing the dynamics of a population.
Subjects: Mathematics, Biology
Keywords: exponential function, logistic model, population
Greek language
Teaching hours: 2</td></tr>
<tr><td>Learning outcomes</td><td>Students take an active role in the learning process and work together to investigate the factors affecting the increase in the size of a population in the accounting mathematical model, they made their arguments and discuss their findings.
Apps were used to evaluate the actions of the pupils and their answers during the course of this exploratory teaching model. It is worth highlighting the active participation of all groups of students in the inquiry learning process.
Students discovered that the learning of the accounting model was very useful for real life situations.</td></tr>
<tr><td>Photos or other relevant material</td><td> </td></tr>
</table>

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW (Observation 1)

Information box

General information	
Dates	11/03/2016
Name of teacher/	Polly (pseudonym)
Years of experience in teaching	
Main teaching subject(s)	Mathematics
Age(s) of students	16-18
Experience delivering lessons on ICT	Experienced

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

First of all, it is part of the topic ‘Exponential function’ visited at the 2nd Grade of upper secondary education (Lyceum). The exponential function cannot however be used for all predictive models, especially in ecology and biology. So starting with this function that students have studied and have used to solve problems, we explore a new model, the logistic growth model, through the provided lab and experiment. Students will explore the parameters of this model.

The lab to be used is virtual and called “Logistic growth”

Using this lab, I have created an inquiry-based scenario, which both at the introduction and in the theoretical background uses the basis of the exponential model. However, via some questions, the students themselves realize that the exponential model cannot be used for all models and this gives them the opportunity to pass to the new model that we want them to learn and explore. What characterizes this model is the fact that it gives multiple representations, i.e. we have the algebraic formula and at the same time we can get the different graphs from changing the parameters. This is very important because many times when we teach functions in mathematics, students cannot make the transfer from the algebraic model to the graph and vice versa. So, the simultaneous recording of both helps them to understand the representations of functions in mathematics in general.

What is your (the teacher’s) experience with using technology-enhanced learning environments and/or inquiry based learning in teaching science/mathematics?

With Go-Lab and ISE I was introduced to the process of the inquiry-based scenarios. At the same time, I had to find the tools with which students could form hypotheses and arrive at conclusions. Basically in the last 2 years, I have familiarized myself with this process. I saw students’ interest and engagement and also how these tools could be introduced in mathematics (and not only in the study of science, as many would say). I have already used them many times and have created scenarios based on these. These help me unify bodies of knowledge, that is to do mathematics and physics, mathematics and biology as today, mathematics and astronomy etc. ILSs give me this opportunity, which I consider very important.

Have you shared an existing ILS or created a new ILS? In the former case, how have you chosen it; have you made any changes in it?

At the beginning, so that I could create my own ILSs and see examples, I studied an existing ILS, but I did not use it in the classroom. Still now, even when I adopt an existing ILS, I do many changes. For example, last year when we did a project on mathematics and medicine, I used the ILS on ‘Inheritance’ and implemented it with my students, but I had done lots of changes/revisions.

I chose this ILS because it was in the framework of the lesson we had developed the project ‘Mathematics and Medicine’ and mainly because it included mathematics knowledge

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

In Phase 1 – the Introduction – I have given the students the collaborative tool 'Padlet'[4] and I want them to do an initial recording/formation of their hypotheses regarding which factors affect population growth, i.e. the parameters of the model they will explore later. I think it will take more time than it should, but I want both to engage them through this and introduce them to a process of collaboration. The two first phases, the Introduction and Theoretical Framework, should last around half an hour. Students will follow the instructions, provided both by me but also attached to the 'Experiment' and explore the model, altering the parameters, creating the graphs, keeping notes using the Go-Lab tool and finally arrive to a conclusion. If we have still some time at the end, I will also give them an exercise to be solved based on this model. Otherwise, they will do it as homework. In addition, in order for them to be able to find out more about the issue concerning this ILS, I have already prepared a bibliography to give them and they will have to prepare a report for next week.

Timing: 80-90 minutes.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

Their knowledge background is very good but they have no experience at all using Go-Lab. This is one of the reasons, I chose this class, to test it… Last year I used it with experienced students, so it was very easy for them and perhaps after a while the results were not as important as with students that use these tools for the first time. Anyway, as I said, they have a good knowledge background, digital skills and they are cooperative, but have never used this particular environment.

As for inquiry-based learning, I think they have done something in science, but I do not have a comprehensive view on what was the framework they used it – whether they have used the 5-step model, or if they were given a problem to solve and then they had to arrive at their conclusions. Usually from what I have seen, they are given a problem to explore and through this to reach their own conclusions. I do not think they have seen the 5-step model before.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

I think that the lesson went well enough or even very well, I am very satisfied. The students were active in the discussion and all showed interest. They took notes, formulated hypotheses and arrived to conclusions both from the graphic and the algebraic representations. I also believe that the results of the cognitive assessment I gave them at the end of the lesson were good - based on the model - from a quick glimpse I had. Given that it was the first time they engaged in such an environment and such a process, I think it went very well.

[4] http://padlet.com

Did you use Go-Lab as you intended to use it, or did you make any changes to your original plan?

Compared to the original plan, the students used that much the digital tools (apps), because they did not have enough time to do so. The collaborative learning tool, “The wall” (padlet) was used very easily and perhaps it was a one of the best means to engage them. Apart from this, the rest of the apps that I had included in the first phases were not very much used.

How did Go-Lab facilitate the achievement of these outcomes?

It helped very much. To start off with, only the virtual lab used, the table with the representation, the tool with the representation of the population and the graph… The fact that we did not start giving the students directly the formula or the law, but they passed from an introduction to a practical framework.

How would you say that the students learned? Individually, collaboratively? How important or not important was this?

In collaboration with each other. There were 2 groups of about 2-3 students each, who discussed and learned. There was no individual learning and I believe this is very important because apart from the cognitive part, they also nurtured collaborative and communicative skills.

How were you assessing the students during the lesson and then at the end of the lesson?

The students got engaged progressively. At the start they were a little numb, a bit strange with the new environment, with what they had to do. Then they got more engaged with it.

How were you assessing that the students achieved their goals during the lesson? In what ways? What was your role?

From their statements, from the discussions they had with each other while working in groups. I recorded what was happening and what conclusions were they arriving to.

As for my role, I was just facilitating the process.

Is there anything else you want to say, that has not been covered already, about today’s experience?

I think that once again today’s lesson helped very much to link real life situations with science and mathematics. This is very effective, because in this way students can realize the role of science and get motivated to learn. I believe that the homework they have to do using the model, given that they will have more time to record in algebraic and graphical forms some conclusions, will also very important.

Would you change anything if you did the lesson again?

I would spend less time in the introduction and theoretical framework and spend more time in the investigation part of the model itself. I would change the distribution of time in the first and the second phase.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Polly (pseudonym)
Subject taught:	Mathematics
ILS (s) used:	Λογιστικό μαθηματικό μοντέλο http://graasp.eu/ils/54cbab42479265d7425bf788/?lang=el
Observation date:	10/03/2016
Observation time:	11h00-12h30
Nr. of students present:	26

Please check the appropriate column for each item in a section, where:

1.) Y = The measure was observed

2.) N = The measure was not observed

3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	Although in her interview the teacher said that she should have used less time for the introduction and theoretical framework phases and more for the investigation phase.
X			Instructor is well prepared for class (apps and computers prepared)	ILS very well prepared. Some of the desktop computers not working so students worked in groups of 2 or 3 in front of one computer. Teacher has all the necessary links in a doc which she shares with the students through the local network. She also has the links on a USB stick, which she passes around.
X			Instructor appears to be confident to use the selected ILS	Yes .She had written it herself.
X			Instructor uses a relevant ILS for the development of his classes	The lesson seems to be an extension of what students had already studied on the exponential function.

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	The teacher uses 4 out of the 5 phases. She runs out of time and thus sets the discussion (5th) phase as a written exercise for homework.
X			Instructor switches from one phase to another (and goes back if needed)	She did not need to go back.
X			Instructor seems to be in control of all the phases of the ILS	
X			Instructor connects the ILS to prior classes or ILSs	Yes, she connected it to the lessons the students had had on exponential function, helping them remember the function’s algebraic representation, and its characteristics (for about 10 mins).

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	Very!
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	She follows their suggestions where appropriate.
X?			Instructor uses appropriate and clear language	The terms and concepts she had to negotiate with students were: law, model, equation, function, variables, exponential change, rate of change. The students do not always see how some of these differ. The teacher does not always manage to clear the confusion.

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
		X	Students work individually from the beginning	Students work in groups of 2 or 3 in front of a computer. There are not enough computers available for students to work individually. Lots of collaboration encouraged by teacher and ILS (e.g. Padlet app). When asked to work individually, one student writes on the computer and the rest of the team write on pieces of paper.
X			Students appear to be clear about the task	Mostly
	X		Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	Some computers did not work, other had difficulties loading the ILS. However, the internet connection seemed satisfactory.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	The teacher does not always manage to clear the confusion.
		X	Students are familiar with ILS	According to the teacher, most of the students work with Go-Lab for the first time
X			Students seem to be motivated with the ILS	

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	See also additional comments below
X			Students are interested with the problem (specific ILS)	
			Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Some students played it safe and held back. Some other were more dominant in the discussion. Students appeared ready to listen to one another. Teacher asked questions and picked which students would answer.
X			Students seem to be supportive during the activity	

General comments
Major issues observed: No major issues were observed. The topic chosen seemed to be a bit challenging for the students. The model was complicated and it involved advanced mathematical knowledge. Not all students seemed to follow all the time; however, they did not give up and stayed on task. The teacher was very ambitious in her goals, which also probably extended beyond her science subject knowledge comfort zone.
Major outcomes observed: The students saw how a mathematical function can be used to describe real and current phenomena, such as population growth.

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW (Observation 2)

Information box

General information	
Dates	18/03/2016
Name of teacher/	Polly (pseudonym)
Years of experience in teaching	
Main teaching subject(s)	Mathematics
Age(s) of students	16-18
Experience delivering lessons on ICT	Experienced

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

The students inquire and experiment in order to understand the Keppler laws as they implement knowledge and laws of mathematics. On the opposite side, the Keppler laws consist of an active field for the understanding of the properties of proportional magnitudes and the properties of the conic section of an ellipse.

Cognitive Subjects: Mathematics (analytic geometry), Physics, Astronomy

Linking mathematics and astronomy

Aims:

1) To understand the properties of conic sections (ellipsis, hyperbole, circle) through exploration of a simulation of the planet’s motion around the sun.

It is part of the mathematics curriculum of 2nd upper secondary school, concerning the study of conic sections.

To understand and explain Keppler's Laws:

First Law: "Planets move in an elliptical orbit, with the Sun being one focus of the ellipse."

2) Exploration of the relation between the period of rotation of a planet and the distance R from the Sun.

Based on the properties of proportional magnitudes (table of values, graph) in Mathematics; explanation and understanding.

Third Law: "If T is the period of a full rotation of a planet around the Sun and R is the mean orbit radius, then T2 and R3 are proportional."

Big Ideas of Science:

Earth is a system of systems which influences and is influenced by life on the planet.

Earth is a very small part of the universe.

All cognitive objectives are new to the students: They have never been taught astronomy, Keppler's Laws are not included in their Physics curriculum and they have not yet been taught about the ellipsis as a conic section. Students are only familiar with the concept of proportionality.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

Introduction (5 mins)

A brief historical overview of the structure of the solar system: Views and opinions.

The planets of the solar system: Watching a video

Basic concepts required to study the motion of the planets

The geometric locus of an ellipse (30 mins)

Using the Geogebra software the students discover and define the geometric locus of the points of an ellipse and the basic property of eccentricity, which determines the motion of planets. In addition, with the help of an animation showing the motion of the planets, students create their own hypotheses about the factors that affect this motion. More particularly, they record their observations about the motion of the planets around the Sun.

- How does their rotational velocity change around the Sun?
- How does the rotational period change around the Sun?
- How does the planets' kinetic energy change?
- How does the planets' gravitational potential energy change?

Basic objective is that students develop their initial hypotheses about the changing variables of the planets' motion.

Investigation (20 mins)

Variables – factors that affect a planet's orbit.

Rotation period – Rotation radius – Rotational velocity

Justification of Keppler's Laws (15 mins)

Students use their physics knowledge to verify the algebraic relationship of Keppler's 3rd Law.

Possible Extension to very useful fields of knowledge:

Explanation and understanding of the phenomena: day-night, change of seasons during the year.

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

Only 2-3 of the students in the class have previous experience with Go-Lab. The rest have not had any contact with environments, where the need to use apps and digital tools in order to take an active role in the learning process.

However, this class is one of the best in school in terms of their grades, their distinctions and their participation in innovative activities. So, I think that they can very easily familiarize themselves with the Go-Lab environment and I do not doubt that they will respond very well.

I do not know what experience they have with inquiry-based learning.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

The students were engaged in inquiry; they got activated to work. The cognitive aim concerning the ellipse was accomplished fully. However, I do not think that the link of mathematics with astronomy and physics became obvious.

Did you use Go-Lab as you intended to use it, or did you make any changes to your original plan?

I think that the ILS was quite big and the students needed more time in each phase; as a result, inquiry learning was "compressed" and children's agency was restricted.

How did Go-Lab facilitate the achievement of these outcomes?

It gives unlimited potential to students to assume roles in learning. The use of apps engages their interest.

Students got to use very useful apps in the environment:

Basic app: the data table to link data with graphs

Wiki was also very useful for the collaboration of the students.

Basic tool was Geogebra.

How were you assessing the students during the lesson and how does this inform your planning?

From observation and record keeping at the time. But also using the evaluation tools (apps) at the end.

If this lesson had taken place 20 days later, when students would have been taught about the ellipse, then I would have modified the ILS, focusing only on Keppler's 3rd Law, and it might have worked better.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Polly (pseudonym)
Subject taught:	Mathematical orbits in the motion of planets (Mathematics and Astronomy)
ILS (s) used:	http://graasp.eu/ils/55bdc2a0b5a072ca556738ec/?lang=el
Observation date:	18/03/2016
Observation time:	12h30-14h00
Nr. of students present:	27

Please check the appropriate column for each item in a section, where:

1.) Y = The measure was observed

2.) N = The measure was not observed

3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	The ILS is quite overloaded with apps and labs and the teacher ends up rushing the inquiry in the 4th phase and barely visits the 5th phase ('Conclusion'). She admits to her students that this lesson would have probably required 3-3.5 hours, if they were to do all the inquiry investigations included in the ILS. In her post-interview the teacher reflected that it would have been better if the students knew the characteristics of ellipse prior to the investigation with Go-Lab.
X			Instructor is well prepared for class (apps and computers prepared)	ILS very well prepared. Some of the desktop computers not working so students worked in groups of 2 or 3 in front of one computer. Teacher has all the links required in a doc which she shares with the students through the local network. She also has the links on a USB stick, which she passes around.
X			Instructor appears to be confident to use the selected ILS	Yes .She had written it herself.
X			Instructor uses a relevant ILS for the development of his classes	The lesson is an introduction to a new mathematical concept (the ellipse) through the study of the motion of planets.

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	The teacher uses mainly the 4 out of the 5 phases, though she also rushes through the 4th phase with the inquiry as demonstration.
X			Instructor switches from one phase to another (and goes back if needed)	She did not need to go back.
X			Instructor seems to be in control of all the phases of the ILS	
		X	Instructor connects the ILS to prior classes or ILSs	The students had not previously studied the concepts involved. However, when needed she referred to a mathematics principle they had previously learned.

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	Very!
X			Instructor makes the ILS interesting to students	
X			Instructor responds to questions clearly and promptly	There are not many questions from the students.
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	
		X	Students work individually from the beginning	Students work in groups of 2 or 3 in front of a computer. There are not enough computers available for students to work individually. Lots of collaboration encouraged by teacher and ILS (e.g. wiki app). When asked to work individually, one student writes on the computer and the rest consult him/her. Moreover, two students who have prior experience with working with Go-Lab environment, are given the role of 'mentor' to help the other students. In practice, their help is not much used.
X			Students appear to be clear about the task	
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	There was a considerable delay loading up the Geogebra lab and then later on one of the simulations. The 'Concept Map' app did not work properly. However, on the whole the internet connection seemed satisfactory.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	
X			Students doubts are managed effectively	
		X	Students are familiar with ILS	According to the teacher, most of the students work with Go-Lab for the first time
X			Students seem to be motivated with the ILS	

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	They only complain at the end for not having enough time to do some of the inquiry tasks.
X			Students are interested with the problem (specific ILS)	
			Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	The lesson was mostly led by the teacher. Students participated – tried out things and answered questions. There were a couple of students who were more dominant and knowledgeable overall. Teacher asked questions and picked which students would answer.
X			Students seem to be supportive during the activity	

General comments
Major issues observed: No major issues were observed. The ILS seemed to be a bit challenging for the students, as it contained lots of new knowledge at the same time as use of a new environment. Not all students seemed to follow all the times; however, they did not give up and stayed on task. The teacher was very ambitious in her goals, attempting too much in the available time.
Major outcomes observed: The students studied the properties of an ellipse in the context of very interesting astronomical observations, such as the motion of the planets in the solar system.

TEACHER INDIVIDUAL PRE & POST SHORT-INTERVIEW (Observation 3)

Information box

General information	
Dates	28/03/2016
Name of teacher/	Polly (pseudonym)
Years of experience in teaching	
Main teaching subject(s)	Mathematics
Age(s) of students	16-18
Experience delivering lessons on ICT	Experienced

Interview summary or transcription

PRE-INTERVIEW

What are the objectives of the lesson? What has preceded it?

This lesson is quite contemporary because of the energy problem and I also consider it quite innovative because the energy production through the phenomenon of osmosis is not taught, but is also not heard frequently in the media.

Aims:

- Understanding of the phenomenon of osmosis.
- Algebraic relation for the calculation of osmosis.
- Development of inquiry skills for the creation of the correct model of energy production.
- The active engagement of all students is required in order to inquire all the factors that affect the phenomenon.

The algebraic study of the formula of osmotic pressure and its variables is verified by the study of the model.

Linking mathematics and chemistry.

All cognitive objectives are new to the students. Also it very rarely happens in the school classroom to have the algebraic formula of a scientific concept as a focus of an experiment.

How do you intend to use it? (A brief description of the intended lesson structure – how much time s/he intends to spend in each phase)

Introduction (5 mins)

The need for introduction of renewable sources of energy.

Introduction – description of the subject of study.

Information about the phenomenon of osmotic pressure / Description of the model for energy production. (10 mins)

This is the first stage for the creation of hypotheses / identification of the factors involved in the process osmotic pressure-energy.

Formulation of hypotheses and creation of a concept map about the factors that affect osmotic pressure (based on the algebraic formula given) (15 mins)

Experiment (35-45 mins)

This is the most important phase for the inquiry of factors.

Conclusions

Synthesis of data measurements and extraction of conclusions..

Few words about your students: What is their experience with Go-Lab and/or other technology-enhanced learning environments? What is their experience with inquiry-based learning?

The students in this Club are very experienced users of inquiry learning environments, since every week they implement a different scenario of ISE/Go-Lab. This is the reason that I chose this particular very high level of inquiry in this lesson.

POST-INTERVIEW

How did the lesson go? Did the students achieve the outcomes you had set for them? How do you know?

I think it went very well, because the students did exactly…, completed at a large percentage a normal cycle of inquiry. That is, they formulated hypotheses and used very well the digital tools; they concentrated on the experiment and tried to… -apart from one team, which did it with the appropriate guidance- to change variables and record conclusions. They found alternative ways to inquire their results and each one had his/her own method of how to infer conclusion. However, they all arrived at correct conclusions.

Did you use Go-Lab as you intended to use it, or did you make any changes to your original plan? Would you use it again the same way?

Exactly as I had intended to. I would use it again in the same way and I deduce that the didactic time available was good enough for a lesson that was neither too tiring, nor too brief. About 60 minutes.

Which was your role in this lesson?

I think I had to intervene very few times. I guided them a little bit in relation to the use of the digital tools. Apart from this, the students had a very active role. So, essentially I created the lesson and the framework, and in the given lesson I explained to them about osmosis and osmotic pressure, which I confess I also had to read about, since my specialism is in Mathematics and did not know what osmosis and osmotic pressure are. So, first I understood it, so that I can explain it to them in the lesson.

How did Go-Lab facilitate the achievement of the objectives you had? Which were your objectives?

To start off, I wanted the students to see alternative approaches to teaching. To escape from the theoretic, teacher-centred approach to a lesson; from the worksheet or the scenario. I wanted to introduce the interdisciplinarity of different subjects, through the use of contemporary environments. To open their cognitive horizons, to learn new things, e.g. astronomy, which is not in the curriculum, chemistry, physics, through the use of very new digital tools; to give them experience in these. Essentially, to cultivate in them a spirit of research, and I believe that I have been mostly successful in this, to make them 'young researchers' as I call the group from the first day.

What aspects of the lesson involved inquiry-based teaching and learning?

The whole lesson is a cycle of inquiry. I cannot say that it is only the experiment. We started by engaging their interest, we went to the theoretical part where they learned what osmosis is, to formulate hypotheses from the algebraic model, to experiment and draw conclusions. It would be wrong for me to say that only some parts had inquiry learning; it was the whole cycle.

How were you assessing the students during the lesson and how does this inform or not your planning for the following lessons?

I walked around the classroom and saw that all students were engaged in an experimental inquiry. I saw the hypotheses they had formulated, so I knew they had started this cycle I had planned for them. And then I saw that all of them had started recording their conclusions, drawing on the graphs they had produced. On the other hand, today that they used the digital tools so well, and the lesson went well as it should have gone, I have put in the end to see exactly how each student went in his/her experiments, his/her hypotheses. I have included the corresponding digital tools available by the environment. And when the lesson works well and the students work well and collaboratively, as they should, I get lots of information from these tools, about the time spent in each phase, and about what they wrote, because I can see what they wrote as files inside.

Next time I do this lesson, if the students are experienced, I will let them do it completely by themselves. I will not intervene at all. I will only give them an introduction about what they will do. And I think that they can respond and do it completely by themselves. About this particular group, I am certain that if I left them alone, they could do it. So then, I would monitor them using the tools in the end, what they have recorded.

OBSERVER SHEET

Go-Lab Observation	
Teacher name:	Polly (pseudonym)
Subject taught:	Producing 'blue' energy by osmosis (Mathematics and Chemistry)
ILS (s) used:	http://graasp.eu/ils/56f5b5ce5829e7041c101839/?lang=el
Observation date:	28/03/2016
Observation time:	14h15-15h45
Nr. of students present:	11

Please check the appropriate column for each item in a section, where:

1.) Y = The measure was observed
2.) N = The measure was not observed
3.) NA = The measure was not applicable

Organization

Y	N	NA	Measure	Notes
X			Instructor uses class time efficiently	In the post-interview the teacher suggested that the lesson went very well, because the students completed at a large percentage the whole cycle of inquiry..
X			Instructor is well prepared for class (apps and computers prepared)	ILS very well prepared. Some of the apps however did not work optimally. She did not always manage to help them overcome their problems with the apps.
X			Instructor appears to be confident to use the selected ILS	Yes, although it covered new subject knowledge for her. The ILS was written by her.
X			Instructor uses a relevant ILS for the development of his classes	The ILS was used in the context of an extracurricular Mathematics club. All knowledge involved was new to the students, who however were familiar with the environment.

Development

Y	N	NA	Measure	Notes
X			Instructor uses the phases of the ILS consecutively	
X			Instructor switches from one phase to another (and goes back if needed)	Some students had to refer to a previous phase to check the hypotheses they had made and test them in the experiment.
X			Instructor seems to be in control of all the phases of the ILS	
		X	Instructor connects the ILS to prior classes or ILSs	The students had not previously studied the concepts involved.

Communication

Y	N	NA	Measure	Notes
X			Instructor is enthusiastic about the ILS	Very!
X			Instructor makes the ILS interesting to students	Yes, using positive comments about the inquiry and what the pupils did.
X			Instructor responds to questions clearly and promptly	
X			Instructor uses appropriate and clear language	

Student introduction

Y	N	NA	Measure	Notes
X			Students appear to be in a positive working climate before starting the ILS	Yes, they have chosen to attend this club.
		X	Students work individually from the beginning	Some students prefer to work in groups of 2 in front of a computer, others individually from the beginning.
X			Students appear to be clear about the task	Students have worked before on the environment.
X			Students have the adequate material/conditions needed to develop the lesson (laptops, tablets, proper internet connection…)	On the whole the internet connection seemed satisfactory. Some of the apps however did not work optimally.

Student interaction

Y	N	NA	Measure	Notes
X			Students are encouraged to participate	Yes, although they seem very engaged anyway.
X			Students doubts are managed effectively	
X			Students are familiar with ILS	They have worked with an ILS before, but this one was new to them.
X			Students seem to be motivated with the ILS	Very!

Student behavior

Y	N	NA	Measure	Notes
X			Students are enthusiastic about the task (online ILS)	
X			Students are interested with the problem (specific ILS)	
			Participation patterns are present during the ILS (Did some play it safe and hold back? Did all participate with adequate consistency? Was there a dominator? Did people really listen to one another? Did anyone interrupt others consistently?)	Students participated with adequate consistency. Teacher asked questions and students offered answers.
X			Students seem to be supportive during the activity	

General comments
Major issues observed: No major issues were observed. The students were very motivated to work with the ILS and stayed on task. Few problems with the use of the apps did not seem to destruct them from their inquiry.
Major outcomes observed: The students studied how the process of osmosis can be harnessed for energy generation. They created their own hypotheses using the Hypothesis Tool and shifted between different representations, i.e. the algebraic formula of osmotic pressure; simulations of the process and graphic models.

TEACHER FINAL INTERVIEW

Information box

General information	
Dates	11/03/2016
Name of teacher/	Polly (pseudonym)
Years of experience in teaching	
Main teaching subject(s)	Mathematics
Age(s) of students	16-18
Experience delivering lessons on ICT	Experienced

Interview summary or transcription

Please describe your experience of Go-Lab so far. E.g. When did you begin? When did you encounter it for the first time? How many ILSs have you written? How many ILSs have you used? How have you used it? What kind of help have you had? And in general, what good and bad experiences have you had with it?

I have worked with Go-Lab systematically for the last two years (in October 2014 approx.). I met Go-Lab for the first time in a Workshop by Elefteria at the Greek Physicists' Association and I became enthusiastic about the process and benefits it appeared to have. Since I was running a project and an after-school club, I immediately got involved and wanted to work with it. At the start, for me as a Mathematician, the process with the inquiry and the 5 phases was strange, because Mathematics teachers usually provide students with worksheets for them to work and draw conclusions. I started to work with the inquiry model through Go-Lab. At the beginning, in order to be able to create my own scenario, I had to see many examples and work systematically. I used 2-3 examples from the platform with my students and saw their positive reaction, their enthusiasm because they had an active role in a very nice and open environment. I started thinking about interdisciplinarity and creating a scenario with maths, physics and astronomy. The first one, I used it with my students inside the project and the club, it went well, giving me the motivation to continue. Two-three months later, I had already created 3-4 ILSs and I started using it with my class. At this moment, something amazing happened.

The students of the project and the club, who had become experienced in the implementations of the Go-Lab scenarios, took the role of mentors for the other students, as a result, students themselves were now giving the lesson to the other students. This was a tremendous and surprising experience. Also the students themselves incorporated the inquiry model and through the platform, at the end of last school year, were looking for ways to create their own scenarios, their own small ILSs, or modify already existing ones. In other words, the students became the teachers through this programme. It was a group of 20 students with special disposition towards science. Students liked working with this environment with the purpose of teaching other students.

What it easier to work with this environment?

Very easy and very interesting. It enthused and engaged them even though last year we had some problems with some the online tools, which were not running smoothly. Students were disappointed when they saw that the tools were not loading properly, or when they wrote info and it was not saved. However, they did not give up. Even I was disappointed at the beginning, when I had created an ILS with very nice apps and tools and it didn't work when implementing it in the classroom. Nevertheless, in the long term this was overcome and everything started functioning smoothly. Students liked it, they liked the topics very much, they had direct contact with real labs and they collected data and analysed it themselves. They felt as little scientists and researchers.

Since it went that well last year. This year I formed a club called "European science knowledge paths" as an extracurricular activity and again we implemented lots of Go-Lab scenarios.

I have used it again 3 or 4 times in my regular 2nd year of upper secondary school class, towards the end when we had covered the required curriculum and I had the opportunity. I would like to use it every week, but it is hard because of the strict conditions of the upper secondary school curriculum.

Could Go-Lab be integrated in that specific curriculum?

Very easily, very easily. Go-Lab has many ILSs which you could be adapted and integrated in the regular curriculum, I myself have already created scenarios integrated in the curriculum of Algebra.

Could you see it as a tool that could be used to replace – instead of using it in addition to – some hours of the regular curriculum?

Clearly yes. I say this with certainty because I have worked systematically with it and can extrapolate that it could be used as a compulsory part of the regular school curriculum for about 10-15 hours per year. To replace lessons of Physics, Chemistry… To replace these lessons, not just to support them. The students could also do Biology, Physics, Maths…

Apart from direct teaching, in what other contexts have you used Go-Lab? Could you have used it as an assessment tool?

I think I do not see it as an assessment tool, when the students work on the platform, they collaborate and acquire new knowledge, but assessment is something I never thought about. Maybe assessment in relation to the use of digital tools, but again, there are some applications that if you do not explain to students, they will not be able use them. I do not see Go-Lab's structure appropriate for assessment purposes. For me it is more like a complete lesson to be used as project work for students, to consolidate knowledge, to offer additional knowledge inside the school curriculum timetable, but it is not an assessment tool – I would not be able to integrate it as an assessment tool.

How many ILSs have you created or have you used so far?

I must have used at least 20. I have created 12 of my own, 5 for primary education and 7 for secondary education. I have to admit that it is easier to teach with the ILSs I created than using others. I find it difficult to use a 'ready' one, actually I have never taken a 'ready' one and use it as it is, I always make changes and adjust them to my own purposes. Otherwise I don't think I would be able to use it them.

You said that you created ILSs for the primary school. Given that you do not teach in primary education, how have you approached the task? Did you look at the textbooks?

I saw the structure of the curriculum at the "Digital School" website, I tried to introduce simple inquiry activities. The process of inquiry does not differ in primary education. But the level of difficulty does differ - in primary education students are not given mathematical equations to solve, they are more focussed on observation, experimentations and analysis of simple data. For all this, we pupils have to use other cognitive functions. I looked a bit at how their curriculum is, but I did not really engage with it. In this sense, I did not encounter difficulties when creating the 5 ILSs for primary, I also had some experience from some implementations I had done through Inspiring Science Education (ISE) and I had already observed how pupils at this ages think. First of all, I noticed their amazing enthusiasm, primary school pupils are 'virgin' to this kind of environments and they get super enthusiastic about seeing a topic that they might remember from something they read in their textbook, but also for the collaboratively work it involves. All of this created the motivation for me to create ILSs for primary in Go-Lab.

How much does Go-Lab help in the collaboration of students and how?

It helps exceptionally. Students sit in 2s or 3s in front of one computer, one works in the environment and the other express their opinions. But I have also worked as follows: at the end of each unit, I asked the members of each team to make a presentation about the topic to the others, sharing their findings with the other teams and other teams adding to them based on their own inquiries. This means that not only they collaborate in pairs, but as a whole class. They liked it a lot, they enjoyed presenting their work.

From the different phases of inquiry, do you value all of them in the same way?

Many times I caught myself spending more time on the first 2 phases, especially when it was a new topic, and less time on the experiment. But I think it is the experiment and the formation of hypotheses where the weight should be put on. Many other times however, I have been carried out and spent more time… What I try to achieve is to spend less time on the first 2 phases, the introduction and the theoretical framework. They could even be given as preparation for the students to do at home. But also the last phase, which concerns the discussion, presentations of the messages learned to their classmates. In other words, if we wanted, we could give the first 2 phases and the last phase as preparation and work respectively to be done at home.

What are the best and worst aspects of Go-Lab according to your experience, from creating ILSs, from using ILSs….? Good or bad issues that you may have faced, in relation for example to its implementation in class, to the technology involved, to using the environment, to using it for learning, to using it for inquiry learning…?

If I had to put them order, I would put the 'inquiry-based learning' first, followed by the technology, meaning its applications. The last would probably be the 'use of an existing ILS', as I mentioned before, I cannot use someone else's ILS. I think that you can only enjoy the real Go-Lab experience if you get to create your own ILS.

Did you ever think that the use of technology worked in a negative or inefficient way in relation to learning?

At the beginning when the software was not running properly. Students were disappointed because it would not load. But this was mainly in the first year, this year everything was running perfectly and quite fast too. It improved very much.

Do you think that other science or mathematics teachers would have, or have had similar experiences?

Unless they seriously get involved with it, with desire/motivation and love for their students and for what they are doing, then they will not find positive results. I have already suggested it to other colleagues, and what they did is basically to project their lesson on the wall. This is not Go-Lab; Go-Lab is the student him/herself doing the inquiry.

I think that maybe the reason why they do not get more involved is because they do not have the technical infrastructure in their schools, but also because they want to avoid the process of setting up the lesson in the computers, preparing and studying the ILSs.

Do you think that the use of Go-Lab in a lesson requires a lot more time than a lesson without Go-Lab?

Its preparation needs more time. But once you have prepared it well, the time that you save in the classroom balances it. In other words, the topic you want to teach, if to do it via Go-Lab and you have prepared it well and set it up properly, it will go much better and faster. E.g., what can I say to my students about osmotic pressure, when they haven't seen themselves the experiment and the instrument, when they haven't experimented with the variables and the formulas? And what can I tell them about craters at the surface of the earth, when they have not been seen the results from the lab themselves?

What you lose in the preparation as a teacher, but you win in the classroom.

How might you expect Go-Lab to be adopted within your school in the coming year or two? What advantages and disadvantages would it bring?

I think that all the results achieved during the last 2 years will serve as perfect examples for dissemination. My scenarios have been implemented, they have worked and they have had results. I have also recorded what students did, and I believe all this might work as a motivation and as an example for other teachers to get involved. Anyway, I will continue to use it because it is a very interesting environment and perhaps with more communication, other teachers may wish to get involved.

Do you think that the use of Go-Lab is more appropriate for any particular age groups, teaching topics or teachers?

As I mentioned, even if I am not a primary teacher nor a science teacher, I have used it with primary school students. I would say the age range cover the whole spectrum from 6 to 20. As for teachers, it depends on the how they approach it because the environment has a lot to offer them, if they are open to exploit it in their teaching.

Do you foresee any major obstacles to widespread adoption of Go-Lab for science teaching?

Schools' technical infrastructure. This is the first and very important obstacle.

Most often the school computer labs have 8-10 computers which are of an old technology and very slow. In most schools I have seen old computers and there is no support for internet access. Wiring could be old as well. Teachers also face difficulty to access the computer lab, as it is seen as "belonging" to the ICT teacher. There the head of school needs to be strong to say that other specialist teachers can use it. Many time however, the heads have given the "custody" of the computer lab to the ICT teacher. They are calm that the responsibility for it is held by the ICT teacher, so often they do not dare to ask/allow other teachers to use it.

How would you enhance Go-Lab's use as part of the existing curriculum?

Especially in Physics and Biology. In mathematics too, but they will need more time to adjust the structure of their teaching in order to be able to use it. This is why I said, there will be more resistance, both by the curriculum authors and the teachers. I have heard from the science teachers that they know about the inquiry cycle from the 2nd phase of their ICT training, so it would be easy for them to integrate it in their teaching and create scenarios.

HEAD OF SCHOOL INTERVIEW

Information box

General information	
Dates	28th March 2016
Name of Head of School	
Years of experience in education	

Interview summary or transcription

11. What is your role within the organisation (or relationship with the organization)?

Head of school.

12. Have you used/heard of online laboratories before your Go-Lab experience?

I have heard of, but not used.

13. How would you characterize the implementation of IBSE in your school, before the Go-Lab experience? Familiarity with the concept and practice or not; Frequent/rare use

I would consider it innovative, even before the Go-Lab experience.

14. How would you characterize your experience with the implementation of Go-Lab in your school? Positive/negative, useful/not useful and why?

Not only positive but also useful. Positive because it helps the students to think, to see science in a different way. This will be seen, when students go to university, mainly to departments of science, for example in the Engineering Department, where they will need to work in labs. Now students enter a lab for the first time when they go to university and are dumbfounded as they do not know where to start. So you start teaching them something from the beginning. The second difficulty is how to teach them to use other sciences, such as Mathematics or Statistics to process the data. Through Go-Lab we succeeded in these two things. OK, we might not have had students making the experiment by themselves, but we gave them the opportunity to see it, which is very positive, so that they can later have the ability to start doing something. You also give students the the opportunity to learn how to process the data, which is very important in order to arrive at a conclusion and what's more, within the synthesis part – to make use of the conclusion and decide what to do. This is where essentially the innovation of Go-Lab is. It is very important too that the student knows that the data s/he processes is real data, scientific data, which is also used by experienced scientists in their research. In this regard, students are given the opportunity to feel that they "participate" in real science in their own way and take it more seriously. In the past, the demonstration experiments we used to do, were often considered by the students as little games, as something specifically set up to show them things. Now you can say: 'here are the data, you draw the conclusions'. Here is where I think Go-Lab gives something different.

15. Do you think that Go-Lab has had any impact on students' understanding of inquiry based learning?

I think this is what the teacher is looking for. This is very important for the students, because they learn how to work in a different way. The learn to put aside the textbook, which is like the Bible and this is a problem. They learn how to work in a scientific way. Go-Lab gives them tools, scientific tools that they can later on use in their scientific career. This is much better than studying another textbook chapter.

16. Does it help teachers implement IBSE?

I believe that if you set it as one of your aims, to incorporate such pieces of the process in your own syllabus, at the start you may need to put some work in to see how best to fit it in your teaching, but then it proves very helpful. In other words, I think that teachers need to work a little at the start to incorporate it in the curriculum where it fits, or where they think it fits. For example, if I wanted to teach students about the standing wave, if they do not see it, or if they do not explore it either in the lab or in a visual way, they cannot understand it; they just learn it as it is and they do not assimilate it. So when you put a question or an exercise to them about it, then it shows that they have not understood it. So as a teacher I am thinking: What can I do to make them understand it in a curriculum hour? I could talk and talk to students and in the end I do not succeed in anything. This is where the lab comes along, it could be a virtual lab. I have created it for example in slow motion to show clearly how it works and how all the points go. This is where it can help. The teacher needs to survey all existing tools and labs (real or virtual) and find those pieces that they need to incorporate in the curriculum to simplify their job. This is why I say that at the beginning you need to put some work in, which however later on will help you significantly.

17. Does Go-Lab also help teachers learn about how IBSE and its different phases work?

We would need a special training session with selected pieces to show how these could be integrated in their curriculum. Because here we need teachers who know how to use computers, who can search for labs, etc. […] We would need a training session to motivate them and give them some basic knowledge. Then, as this is dynamic and you can see what other people have done, you participate in groups, etc., you may acquire some experience of how to incorporate it in your teaching. All this has an additional characteristic, you can give it to students as homework. It is very easy, because the student can access the software or database to work from home; it does not have to be present in the classroom. I think this works better than if you gave them a problem to solve at home.

18. Have you seen teachers who are not using it yet, to be motivated to find out more about it?

There was a mass teacher training programme on the use of ICT in teaching, which I think overall was successful, though I cannot concretely evaluate its impact or how cost effective it was. But what I can say is that it helped motivate teachers to start looking, as there are many databases or virtual labs around they can make use of. I think that this worked as motivation, because it also provided them with a certification which counted for promotion, etc. However, I do not know if at the end of this process teachers also adopted and used these tools in their teaching.

19. Do you use school teacher board meetings for dissemination purposes of innovations, good practices? Are there any presentations of teachers who have tried things in their classrooms? Any discussions?

No, this does not happen. The meetings are mainly for administration purposes, and their pedagogic character has to do only with how each class performs. There are some attempts towards this by the coordinators of some subjects, but I am not satisfied with the result. It is something that I am concerned with. We started keeping a record of all the activities done in the classroom. Every year I ask teachers to write down what activities they have carried out, how they have planned them and what are the (intended) outcomes. I get every year a report from all the teachers. I can't say that I am very satisfied with it. I think it is more like a routine exercise they do; there is no result coming out of it. I think about how it could be coordinated better, so that each one can get information from the other. But this is reality, the activities in school happen without any planning/programme. Usually teachers come with something they have in their minds and say 'I want to do this, it is very good…' etc. Most often you do not want to intervene and say 'don't do this activity, or do this', you let them do it. It does not happen however under a given coordinated framework. And this is where the difficulty is. Now, this difficulty has solutions; it could happen, not only through specific guidance, but also through the philosophy of a school. I think that we who are 'model' schools could define our philosophy or have a ‘special group’ through which these activities should pass, or which will coordinate which activities can come together to bring a result. In a way, we can say that the way these activities proceed is an anarchic process. There is no coordination leading to results.

20. How would you characterise the impact of Go-Lab on the students? Do you have a view of whether these implementations had an impact?

We do not have a ready result of an evaluation of the programme yet, but if I judge from what I saw in the implementations I was present, students were interested – they were not indifferent. If you give children something different that interests them, you change immediately the class climate, what they expect to see in the classroom, which is for the teacher to go in and do the lesson on the blackboard. Given that this took place towards the end of the day, when students were tired, if I judge the interest they showed – this was an element that gave me the impression that something was happening there. The results will show us.

21. How do you plan to use Go-Lab in the future?

It is very important to see how this can be incorporated in the educational processes – i.e. through guidelines, because a big problem is that the educational process is strictly restricted within given frameworks. It gives very few margins to teachers who wish to innovate, to do something different and if they try to do something different, they will get very tired with all the bureaucratic procedures, etc. This [Go-Lab] could enter [the curriculum], either if these restrictive guidelines were in different form, or if they gave teachers more freedom to do things. If we see other educational systems, in essence, teacher design and develop their curriculum and their programme. Here, teacher do not develop their curriculum; a paper comes, which says ‘you will do one, two, three’. Then another paper comes to say ‘this is how you will do the one’, ‘you will do these exercises from the two’, and ‘you will do this lab from the four’. These are very restrictive. Some people in the Ministry, sit down, write a programme and they give it to you. Teachers have to work as if they were following a recipe book. As a Physicist, I do not accept this, working as if I had to follow a recipe book; I could introduce other elements who could bring a result. But at this moment, this cannot be done and this is a very big problem for the introduction of such elements, like Go-Lab, in teaching. It also an issue of time restriction, and sometimes if you try to do something, you have all the people on the outside […] saying ‘what is this that the school is trying to do?’ etc. - when you try to do something outside the pre-defined one by the Ministry. It is certain that it will contribute [positively], but it is very difficult, and if a teacher does not have the necessary encouragement to go through this process, s/he says ‘I covered the set curriculum until there and I am alright’. This is what usually happens.

MAJOR OUTCOMES

The main themes arising from this case study can be summarized as follows:

- This case study serves as an interesting example of cross-curricular cooperation within Go-Lab. As expressed by the teacher when referring to the ILSs: *“These help me unify bodies of knowledge, that is to do mathematics and physics, mathematics and biology as today, mathematics and astronomy etc.”*
- Gradual incorporation of Go-Lab to her teaching. Initial experimentation through extracurricular activities such as an after-school maths club and a student’s project, testing of the ILSs during regular lessons, adaptation of the ILSs to comply with the national

curricula, more frequent implementation in regular lessons and finally, even outreaching developments such as ILSs design and implementations for primary students.

- In connection to the prior two points it is also worth reading the teachers description of the student's involvement: *"The students of the project and the club, who had become experienced in the implementations of the Go-Lab scenarios, took the role of mentors for the other students, as a result, students themselves were now giving the lesson to the other students. This was a tremendous and surprising experience. Also, the students themselves incorporated the inquiry model and through the platform, at the end of last school year, were looking for ways to create their own scenarios, their own small ILSs, or modify already existing ones. In other words, the students became the teachers through this programme."*
- Regarding this particular ILS, even if the chosen topic seemed challenging (the model was complicated and it involved advanced mathematical knowledge), students did not give up and stayed on task. The teacher was very ambitious in her goals, which also probably extended beyond her science subject knowledge comfort zone (cross-curricular).
- The teacher did not find Go-Lab as it is, useful for assessment purposes. She does not believe it has an appropriate structure for this kind of use.
- It is also mentioned several times during the interview the improvement of the platform itself from one year to another. Especially initial issues concerning the malfunctioning of apps and other tools when implementing the lessons. It is worth noticing that this kind of issues did not stop the teacher and the students from using Go-Lab.
- As for Go-Lab helping enhancing IBSE methods: "if you set it as one of your aims, to incorporate such pieces of the process in your own syllabus, at the start you may need to put some work in to see how best to fit it in your teaching, but then it proves very helpful."
- Teachers attending ICT for teaching courses rewarded with official certificates (valid for future promotions etc.)

4.2.4 Mini case studies

The purpose of the light case-studies is to learn about the classroom use of the Go-Lab elements in schools across Europe. WP8 was keen to understand how this experience was for teachers and their students and what, in their opinion, were the benefits and drawbacks of using those elements. WP8 was also interested in learning the outcomes and impacts this experience had on students and their teaching work. For these purposes, and if possible, we asked teachers to collect multimedia records, texts and other types of evidence related to the implementation of Go-Lab in their school.

As a "thank you" to their teachers for their work, a selection of these case-studies will be used for dissemination purposes and will feature in the Go-Lab website and social media.

General Guidelines:

Teachers have been provided with a list of questions as well as a brief description of what kind of information they could provide us with for each one of them.

In some of the participating countries teachers have filled in the form on their own while in others, the National Coordinators (NCs) have used these questions and they have conducted phone or face to face interviews in order to collect teachers' feedback. In this case, questions have occasionally been adapted in order to capture teachers' experience and allow them to fully describe their experiences.

4.2.4.1 Bulgaria (4)

Research themes/questions:

In the case of Bulgaria, the mini case studies have been focused on the following research questions:

1. Background information about you, your school and students that participated in Go-Lab
    a. Your teaching background, your school and your students
    b. Other staff members in your school involved in the Go-Lab activity
    c. Any contact with representatives of organisations who created this laboratory/ILS
2. Why did you choose the specific laboratory/ILS?
    a. Did you have to adapt the ILS in any way?
    b. If yes, what did you do and how?
3. Did you have to adapt the ILS in any way? If yes, what did you do?
    a. The actual process of using the Go-Lab ILS/laboratory in your classroom
    b. Students' behaviour and response to the practice.
4. Outcomes for the students
    a. Students talking about their experience and if they have enjoyed the activity
    b. Students describing what they have learned
5. What was good about the ILS/laboratory you have used and what were the drawbacks?
6. Would you do it again and would you recommend it to your colleagues?

Case study #1: Tsetsa Hristova

Your Name: Tsetsa Hristova	**School:** (PG po KTS) Vocational Secondary School of Computer Technologies and Systems	**ILS/laboratory used:** BHIMS	**Date:** 30/06/2016
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
1. Background details about: 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity – no 1c. Any contact with representatives of organisations who created this laboratory/ILS	☒Video/audio recording of you talking about the background details ☒Text ☐Will discuss in a follow-up telephone call		(e.g. Audio file attached "sample.mp3") 1a. My school is a Vocational Secondary School of Computer Technologies and Systems (PG po KTS). My students are 14-19 years old. 1b. I shared information with my colleagues, but I am not sure if they used ILS. 1c. Yes, with Eleftheria Tsourlidaki and professor Rosa Doran.
2. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☒Video/audio recording ☒Text Will discuss in a follow-up telephone call		2a. No
3. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students' behaviour and response to the practice.	☐Video recording during the activity in your class ☐Photos capturing the key moments of the practice ☐Written description of the process		3a. This ILS was used during the Astronomical club activities. 3b. Students liked to use it.
4. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		4a. I'm Marty Vasilev. I study in the Vocational School of Computer Technology and Systems (PG po KTS) in Pravets. I have been involved at BHIMS ILS from the Go Lab project. I noticed on the website that it is very well done and that the information is explained in plain language. Also, the studies in the site are very well done, so you learn about a lot of jobs. Generally, the information is very well systematized and I learned many new things. 4b. We learned about the using of online astronomical labs, SalsaJ and black holes.
5. What was good about the ILS/laboratory you have used and what were the drawbacks?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		It was very well done ILS
6. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		Yes, I will use it again and I will recommend it to my colleagues.

Case study #2: Tsetsa Hristova

Your Name: Tsetsa Hristova	**School:** (PG po KTS) Vocational Secondary School of Computer Technologies and Systems	**ILS/laboratory used:** Electrical circuit lab	**Date:** 15/12/2015
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
7. Background details about: 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity – no 1c. Any contact with representatives of organizations who created this laboratory/ILS	☒Video/audio recording of you talking about the background details ☒Text ☐Will discuss in a follow-up telephone call		(e.g. Audio file attached "sample.mp3") 1a. My school is Vocational Secondary School of Computer Technologies and Systems (PG po KTS). My student are 14-19 years old. 2b. I shared information with my colleagues, but I am not sure if they used ILS. 1c. No
8. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording ☐Text Will discuss in a follow-up telephone call		2a. No
9. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom. 3b. Students' behavior and response to the practice	☒Video recording during the activity in your class ☐Photos capturing the key moments of the practice ☐Written description of the process		3a. This ILS was used as homework 3b. Students liked to use it.
10. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		4a. https://www.youtube.com/watch?v=ZJ_PnB3yaH0 4b. We learned about different circuit labs and enjoyed with this experiments.
11. What was good about the ILS/laboratory you have used and what were the drawbacks?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		Very well done ILS.
12. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		Yes, I will use it again and will recommend to my colleagues.

Case study #3: Tsetsa Hristova

Your Name:	School:	ILS/laboratory used:	Date:
Tsetsa Hristova	(PG po KTS) Vocational Secondary School of Computer Technologies and Systems	Is Radioactivity always harmful for humans?	15/06/2016

Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*	**Answers (text):**
13. Background details about: 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity – no 1c. Any contact with representatives of organizations who created this laboratory/ILS	☒Video/audio recording of you talking about the background details ☒Text ☐Will discuss in a follow-up telephone call	(e.g. Audio file attached "sample.mp3") 1a. My school is a Vocational Secondary School of Computer Technologies and Systems (PG po KTS). My student are 14-19 years old. 2b. I shared information with my colleagues, but I am not sure if they used ILS. 1c. No
14. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording ☐Text Will discuss in a follow-up telephone call	2a. Yes 2b. I started a translation to Bulgarian language, but I still have not finished.
15. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students' behaviour and response to the practice	☐Video recording during the activity in your class ☐Photos capturing the key moments of the practice ☐Written description of the process	3a. This ILS was used as homework 3b. Students liked to use it.
16. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)	4a. https://youtu.be/0qsllyJyUyI 4b. We learned about the use of radioactivity on different ways and enjoyed it.
17. What was good about the ILS/laboratory you have used and what were the drawbacks?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)	This was a very well done ILS.
18. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)	Yes, I will use it again and I will recommend to my colleagues.

Case study #4: Tsetsa Hristova

Your Name: Tsetsa Hristova	**School:** (PG po KTS) Vocational Secondary School of Computer Technologies and Systems	**ILS/laboratory used:** The power of electromagnetism	**Date:** 12/06/2016
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
1. Background details about: 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity 1c. Any contact with representatives of organisations who created this laboratory/ILS	☐Video/audio recording of you talking about the background details ☒Text ☐Will discuss in a follow-up telephone call		(e.g. Audio file attached "sample.mp3") 1a. My school is Vocational Secondary School of Computer Technologies and Systems (PG po KTS). My students are 14-19 years old. 2b. I shared information with my colleagues, but I am not sure if they used ILS 1c. No
2. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording ☒Text Will discuss in a follow-up telephone call		2a. Yes 2b. I started translation at Bulgarian language, but still didn't finished.
3. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students' behaviour and response to the practice	☐Video recording during the activity in your class ☐Photos capturing the key moments of the practice ☐Written description of the process		3a. This ILS was used as homework 3b. Students liked to use it.
4. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		4a. Hello, my name is Valdemar Marinov and I study in the Vocational secondary school for Computer technology and system, Pravets town, Bulgaria. I have very good opinion for the Go Lab project. I used "The power of electromagnetism" as homework The information given in the page is very good, adequate for a non-physician but a "regular" person to learn. The site is very user-friendly, unlike many other similar sites. Other good thing of the site is the good animations, demonstrating the problem. 4b. We learned about the electromagnetism and enjoyed.
5. What was good about the ILS/laboratory you have used and what were the drawbacks?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		It was a very well done ILS.
6. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		Yes, I will use it again and will recommend it to my colleagues.

4.2.4.1.1 Conclusions

- The ILS's were implemented in vocational schools, which was deemed useful to learn skills and as a sort of career orientation opportunity.
- The main positive aspects about ILS are the simplicity of the language used, as it was considered adequate for the students' level as well as the variety of topics and concepts available and the user-friendliness of the website.
- The modifications needed for the ILS were focused on translating it to the language in which it is going to be used (in this case, Bulgarian).
- Students' feedback was mostly positive.
- Teachers' feedback was equally good. Those implementing ILS's will use them again and would also recommend them. Nonetheless, while other professionals were informed of the resources available, it is not assured it will be used by other professionals.
- Only some colleagues used Go-Lab resources. Better dissemination might be needed.

4.2.4.2 Estonia (3)

Research questions:

Case Study #1

7. Background information about you, your school and students that participated in Go-Lab
8. Why did you choose the specific laboratory/ILS?
9. Did you have to adapt the ILS in any way? If yes, what did you do?
10. How did the implementation of the ILS go within your classroom?
11. How did the students behave during the whole process and what did they learn?
12. What was good about the ILS and what were the drawbacks?
13. Would you do it again and would you recommend it to your colleagues?

Case Study #2

1. Background information about you, your school and students that participated in Go-Lab
2. Why did you decide to use Go-Lab?
3. How did the implementation of the ILS go within your classroom? What were the drawbacks?
4. Would you do it again and would you recommend it to your colleagues?

Case Study #3

1. Background information about you, your school and students that participated in Go-Lab
2. Why did you decide to create your own ILS?
3. How did the implementation of the ILS go within your classroom? What were the drawbacks?

4. How did the students behave during the whole process and what did they learn?
5. Would you do it again and would you recommend it to your colleagues?

Case study #1: Ulle Kreos

Date:	26/04/2016
Interviewer:	Mario Mäeots
Type:	Video conference interview via Skype

1. Background information about you, your school and students that participated in Go-Lab

- Teacher: Ülle Kreos
- School: Kuressaare Vanalinna School (http://www.vanalinna.edu.ee)
- Subject: Biology
- Students: 45 students from 8th grade (aged 14-15) and 36 students from 9th grade (15-16)
- ILS: http://graasp.eu/ils/5704b96cc3ddb608c844ad19/?lang=et

2. Why did you choose the specific laboratory/ILS?

I used an inquiry learning space (ILS) that is based on "Euglena: A Remote Online Microbiology Lab". This ILS fits very well with the Estonian science curriculum and it looked really interesting to me. In our school, it is impossible to conduct that kind of experiments that is why I decided to use this ILS in my biology lessons.

3. Did you have to adapt the ILS in any way? If yes, what did you do?

Yes, I had to adapt the ILS because the template that I used needed additions. First, everything was in English, so I translated everything from English to Estonian. Then I inserted additional apps and a video in the ILS. For example, into the Orientation phase I added a video about Euglena and links to the Purpose games that I used as a knowledge test. For research question formulation, I added a Question Scratchpad in the Conceptualisation phase. I prepared pre-defined terms that students could use for formulating a research question.

I was in contact with the lab owner from Stanford University too. The main aim was to first learn exactly how the lab works and to be sure that everything goes smoothly on the day I use the Euglena lab. The lab owners were more than happy to help me.

4. How did the implementation of the ILS go within your classroom?

In general, everything went very well. All the Go-Lab apps and videos worked smoothly. After the lessons, I collected feedback from the students, which was positive. Students really enjoyed using the Euglena lab. The only thing they did not like was that they had to wait for their turn to do experiments in the Euglena lab.

The only problem we had (only two or three times) was that, when the lab session started, the Euglena were not visible at all.

5. How did the students behave during the whole process and what did they learn?

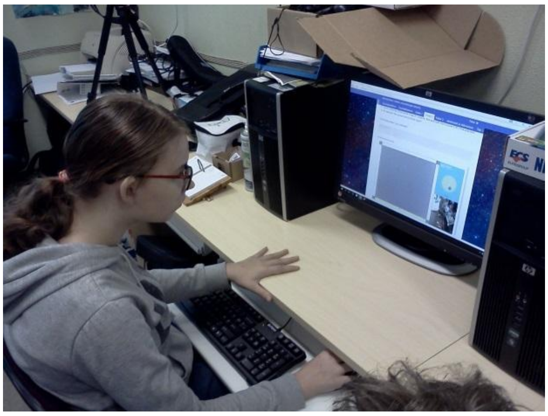
I did not detect any behavioural problems during the lesson. All the students were highly motivated to use the ILS, and I think it was because it was something new for them. I used these lessons as reviewing lessons because we had covered this topic earlier and it seemed a good opportunity for re-testing students' knowledge about protozoicis.

6. What was good about the ILS and what were the drawbacks?

Like I said, everything worked smoothly. The students wrote in their feedback that 1 minute was not enough for conducting an experiment. What I also noticed was that the students had difficulties with the research question formulation. This is something that they do not do very often and thus, I shortly explained it to them at the beginning of the lesson and offered additional help during the whole lesson, if needed.

7. Would you do it again and would you recommend it to your colleagues?

Definitely I will use the ILS again and I am ready to recommend it to my colleagues. I see these ILSs as good examples for showing how to conduct experiments, etc. Also, I am ready to share Go-Lab possibilities with our local teachers. I have been head of the local teacher community for 16 years and I can say that I´m sure those teachers are motivated enough to use Go-Lab.



Case study #2: Dmitry Fedotov

Date:	04/05/2016
Interviewer:	Mario Mäeots
Type:	Video conference interview via Skype

5. Background information about you, your school and students that participated in Go-Lab

- Teacher: Dmitry Fedotov
- School: Institute of Informatics and Computing (http://www.iati.ee/)
- Subject: computer graphics, web design, programming, 3D modelling
- Students: High school (16–18)
- ILS(s): http://graasp.eu/ils/56dc6ac55829e7041c100aa6/?lang=et
  http://graasp.eu/ils/56b8c6865829e7041c0ff81f/

6. Why did you decide to use Go-Lab?

I participated in an in-service course conducted by the University of Tartu where Go-Lab was introduced. I saw great potential in the Graasp environment for improving my lessons. Thus, I decided to create ILSs for my courses where students could not only easily find all the materials in one place but could also adapt different tools (e.g., Padlet) and apps (e.g. File Drop) to support the learning process. I am teaching ICT-related topics like Java Script, AutoCAD etc.

7. How did the implementation of the ILS go within your classroom? What were the drawbacks?

The good thing was that everything went according to the plan. Students mostly used these ILSs during their practicums. I applied different methods within the ILS (e.g., group work). We also tried to work with tablet computers. These were not so convenient to use, especially when students worked in groups. When I experienced some technical issues I contacted the Go-Lab technical team.

8. Would you do it again and would you recommend it to your colleagues?

Yes, I will use Go-Lab again and will recommend it to my colleagues as well. I have already collaborated with one basic school science teacher for whom I programmed a recycling lab (see Figure 58). All the graphical solutions were done by my students during their computer graphics course. The lab was used by science teacher Elena Kudashova who integrated it into hers ILS (http://graasp.eu/ils/5715e28dc3ddb608c844b2da/?lang=et).

Figure 58. Recycling lab programmed by Dmitry Fedotov.

Case study #3: Elena Kudashova

Date:	04/05/2016
Interviewer:	Mario Mäeots
Type:	Video conference interview via Skype

6. Background information about you, your school and students that participated in Go-Lab

- Teacher: Elena Kudashova
- School: Lasnamäe School (http://www.lpk.tln.edu.ee/ee/)
- Subject: geography, science
- Students: students with special needs (learning difficulties)
- ILS: http://graasp.eu/ils/5715e28dc3ddb608c844b2da/?lang=et

7. Why did you decide to create your own ILS?

While I did not find any suitable lab or ILS to teach the topic of recycling to students with special needs (learning difficulties), I still wanted to use the Go-Lab possibilities. Thus, I asked Dimitry Fedotov, from the Institute of Informatics and Computing, to programme a recycling lab, see Figure 59 that would be suitable for my students. It was beneficial to both of us because Dimitry could involve his computer graphics course students to achieve their practicum goals and I could use it in my lessons. Based on this lab, I created my own ILS. I integrated several apps from the Go-Lab portal into the ILS (e.g., Concept Mapper, Input Box).

8. How did the implementation of the ILS go within your classroom? What were the drawbacks?

My students are used to learning using computers, so I did not detect any major issues, only some technical ones. The Padlet app did not work properly on tablet computers, so later I just removed it from the ILS. In general, the implementation of the ILS went well.

Figure 59. Screenshot of the ILS about recycling uses.

9. How did the students behave during the whole process and what did they learn?

The students enjoyed the learning process. I did not notice any behavioural issues during the lesson. The students used the recycling lab to learn the principles of the recycling process. It was a good alternative to their regular lessons.

10. Would you do it again and would you recommend it to your colleagues?

Yes, I will continue using Go-Lab. I have already shared this ILS with one of my colleagues who wanted to use it. Also, I was invited to the chemistry teachers' conference this August. There I will make a short presentation about the ILS. Basically, I will share my experiences with the implementation of an ILS.

4.2.4.2.1 Conclusions

- On the one hand, the main incentive to use already existing Go-Lab ILSs is its adaptability to the country educational curriculum. On the other hand, the creation of new ILSs would normally be due to the need to use a particular ILS that can be adapted to certain content needs.
- The main advantages of using ILS's are those of giving a good alternative to regular classes and providing them with a new innovative activity. It is also very useful to carry on experiments when the equipment needed is not available. Moreover, some ILS's could be

introduced in different lessons, due to the different resources they incorporated (e.g.) which was considered as extremely useful.

- Another advantage (when creating a new ILS) is the possibility to have all the materials in a same place and being able to adapt and to introduce new tools/apps (e.g. Question Scratchpad) in it.
- The main modification needed in already existing ILS's are translations to the language used in the school. Sometimes, although not usually, adding of some additional information was also necessary.
- When using Go-lab laboratories, it was also mentioned as quite useful to be in contact with the institution/individual owning the mentioned lab.
- Regarding the implementation of ILS's, while the students' feedback was really positive, some technical problems were detected. In one of the cases, the Go-Lab technical team was contacted.
- Teachers' feedback on using the Go-Lab ILS's was equally good and they stated they would use it again and would recommend it to colleagues.

4.2.4.3 Germany (4)

Research themes/questions:

Case Study #1 #2 #3

1. Background information
2. Usage of Go-Lab
3. Building and adapting of ILS's
4. Implementation of ILS's in class: Now, please think about one of your implementations and answer the following questions according to this implementation
5. Follow-up: What do you do after using an ILS in class?
6. LA-Apps: In the Go-Lab repository, there are some apps that help teachers with looking at their students' learning outcome and artefacts.
7. Will you be further using ILS's and will you be promoting them to your colleagues?
8. Do you have any further improvement suggestions for Go-Lab?

Case Study #4

1. Background information
2. Go-Lab in general
3. Working with Graasp: Building and implementing ILS's
4. Follow-Up: Learning Analytics Apps
5. The students' opinions
6. Remembering a specific implementation
7. Feedback on Go-Lab

Case study #1: Jörg Haas

This interview has been reconstructed from a telephone interview.

1. Background Information on Jörg Haas

- Name your school and the city you work in: Jakob-Fugger-Gymnasium, Augsburg
- What subjects do you teach: Physics, Mathematics, Computer Science
- How old are your students: 12-18 years' old

2. Usage of Go-Lab

a. When and how did you get in contact with Go-Lab?

During a meeting organized by European Schoolnet about a project called Global Excursion in 2012, in Rome. The objective of the meeting was to have an online exchange of teaching material with colleagues. There I got acquainted with Go-Lab. I have also been part of the Go-Lab summer school in 2014.

b. What was crucial for you to start integrating ILS into your lessons?

The possibility to combine many different things in a same ILS. In comparison to the Global Excursion project, only offering online presentations, is that Go-Lab offers learning environments in addition to the labs and apps. Some apps in particular (like the concept mapper) are very helpful. Also, all of the Go-Lab different components can be integrated in an easy way so in the end it just looks like one piece.

c. Have you been able to get your colleagues into using Go-Lab?

I have tried to promote Go-Lab to my colleagues and have even presented it in one of my teacher meetings and after that, I think a few of them started working with labs as stand-alone, at least.

3. Building and adapting of ILS's

a. Do you build your own ILS's on Graasp or do you adapt already existing ones? Why?

Yes, I do build my own ILS, but I think that I could build more if I had more time. I have also used existing ones and adapted them to my needs.

b. Do you exchange ILS's with your colleagues or publish them on golabz.eu?

I like to keep the ILS's to myself so I don't have to be too conscious about their content. A problem at my school is that all the teachers are used to working with their own platform, Moodle. Therefore, it is not easy to establish a new platform and make teachers use it.

Moodle is pretty easy to work with for teachers because they can simply organize their students there and provide them with tasks. But sometimes I try to integrate links of labs into Moodle and makes his students describe their work in Moodle afterwards. I would like to have an easier way to integrate things into Moodle, though.

c. How often do you use ILS's in your classes? When and why do you use them (instead of having a "traditional lesson"?

Up to now, I have been using ILS's in my physics classes because a lot of experiments cannot be conducted in class as real experiments or are too fragile, costly, or rare to get your hands on. Sometimes, I even use ILS's as homework for my students so they can figure out how to use, for example, remote labs on their own, at home. Most of the time, I use ILS's to deepen the already existing knowledge of my students on a topic; for example, on electron diffraction or on the photoelectric effect. I also like using the Hypothesis Tool and the Data Plotter, but mostly I put the links of those apps and labs into my Moodle platform so students can use them there and tell me about their experiences and outcomes, afterwards.

d. Preparation: Do you talk with your students about the topic and the ILS before using the ILS in class?

Sometimes, I do it the other way round, as some kind of confidence-building measures: For example, when using the Rutherford experiment in class, I let my students to first try it out at home. The next day in class, they conduct the experiment as a real experiment to validate the outcome of the virtual experiment.

4. Implementation of ILS's in class: Now, please think about one of your implementations and answer the following questions according to this implementation.

a. Which ILS did you use and why did you choose it?

I built one myself (about the Rutherford experiment) because this way it fits my lesson and students.

b. Did you build the ILS yourself or did you use an already existing one that you adapted?

I built it myself, searching for information and other things to accompany the experiment.

c. How did the implementation in your class go?

First, a lot of the students played around, clicking buttons and trying out things until they found out how everything worked. Then, they started focusing on different tasks like formulating hypotheses, conducting the experiment, validating the hypotheses, drawing conclusions, and preparing their results to present during the next lesson before the real experiment had to be conducted in class.

i. What was the duration of usage of the ILS?

It took the students one didactic hour to work with the ILS and another one to present their outcome and conduct the real experiment.

ii. How did the students work with the ILS (in groups, alone...)?

Students had been provided with 8 notebooks and were working in groups of two in class, since I think the outcome is better if they work in pairs.

iii. Have there been any problems? Were you able to find a solution? How?

No, there have been no problems because the students were already used to working with ILS's and labs.

iv. **What did the students learn?**

Mostly, they learned about the topic itself, because they were already used to working with Go-Lab.

v. **What opinions did the students have? Did they find anything especially negative or positive? Did they say something to using ILS's in general?**

They just started working with the ILS and I have the feeling they welcomed the change in working in class.

vi. **Did the students have fun?**

Definitely, because they were able to do something on their own instead of just having to watch him conducting the experiment.

vii. **Did any problems occur on side of the students, for example, did you have to explain more things than usual?**

No.

viii. **Could you see any positive effects for the students after using the ILS (memorizing the subject matter, increased problem solving skills, working better on their own, using a scientific approach for other problems…)?**

It is quite hard to say whether -for example- the students' ability to solve problems might increase by using ILS's. Even though, I think that working with ILS's kind of educates them in some way, because they learn to scientifically work on their own.

5. Follow-up: What do you do after using an ILS in class?

a. Do you talk with your students about the implementation afterwards?

No, because -usually- the next topic is following and there is hardly time to reflect on an earlier lesson. Also, I really like ILS's as a medium to teach my students something. Nonetheless, to me, they are not more than something that facilitates his lessons and I do not see any need to talk with my students about the method itself.

b. Do you have a look at your students' learning outcome (the artefacts)? Where (using the Vault vs. having the students upload or send you something)? Afterwards or during the usage, for example, with the help of certain apps?

Mostly, I let students present their results in class. If not, I make them upload things in Moodle, because every student has their own account and I can just click on a student's name and find an overview on all of their artefacts. I would welcome a permanent user name for the students in ILS's so I would be able to recognize them more easily there.

c. Can you draw any conclusions from the different learning outcome of your students (for example, concerning their quality, what has been learned and understood, focusing on a topic…)?

Yes, considering the different qualities of the students' outcomes, I can easily guess which students might have worked with the experiment more seriously and which didn't.

6. **LA-Apps: In the Go-Lab repository, there are some apps that help teachers with looking at their students' learning outcome and artefacts.**

   a. **Have you ever used one of those apps? Which ones (e.g., Action Statistics, Concept Cloud...)? How and when?**

I have had a look at them but I did not try them out yet. Even though I like being able to see how long each student has been working on what, I still think it is difficult to track students' behaviour, because they would need to agree on me having a look at their learning processes. Still, I think that it is extremely helpful to see what students are doing or have been doing and thus being able to intervene and offer help, if needed.

   b. **Do you have any functionality in mind that might be of help for you and that does not already exist as an app?**

Yes, I would like to have a tool that -for example- generates a PDF of all existing hypotheses of a class (so I don't have to gather them somewhere else); or something that clearly shows what each student has been doing in the ILS, "pre-judges" the hypotheses and tells me, for instance: "the hypotheses of 5 students have been good, of another 5 have been less good", and so on.

7. **Will you be further using ILS's and will you be promoting them to your colleagues?**

Yes, I will definitely use ILS's in the future. I think that the already existing (in addition to further German translations of apps, labs, and ILS's) will contribute to more of his colleagues getting interested in Go-Lab. Especially, the possibility to just use already existing labs without having to change that much is a good possibility.

8. **Do you have any further improvement suggestions for Go-Lab?**

Even more translations.

Case study #2: Jürgen Möllmanns

1. **Background Information on Jürgen Möllmanns**

1. Name your school and the city you work in: Privates Don Bosco-Gymnasium, Essen
2. What subjects do you teach? Physics, Chemistry, Computer Science
3. How old are your students? 12-17 years' old

2. **Usage of Go-Lab**

   a. **When and how did you get in contact with Go-Lab?**

I came across Go-Lab 4 years ago on a MINT-Tag in Essen where schools were thought to present their program and ideas of learning. There, I got in contact with Sven Manske, who had been representing Go-Lab there. When learning about Go-Lab's ideas and possibilities, I especially liked the already existing online experiments.

   b. **What was crucial for you to start integrating ILS into your lessons?**

I had always been thinking of building such an online experiment myself, especially using remote labs to give students the possibility to work with rare material so I was really happy when I heard about Go-Lab. Being invited by Sven, I participated in a Go-Lab Workshop at the University Duisburg-Essen in Duisburg. There, I learned a lot about working with Graasp and how to build my own ILS's.

c. Have you been able to get your colleagues into using Go-Lab?

I had already promoted it to a lot of colleagues without success, unfortunately. But there will be a lot of new colleagues soon and I will try to show them the advantages of using ILS's in class because I think Go-Lab is a wonderful addition to school lessons.

3. Building and adapting of ILS's

a. Do you build your own ILS's on Graasp or do you adapt already existing ones? Why?

Today I really like using all kinds of ILS and apps in all of my classes, no matter the students' age. In general, I like to use easy learning environments which focus on the lab itself rather than providing my students with too much information at once. I always build my ILS's myself because then I can ensure the content fits my lesson plan. In the beginning, working with Graasp had been a bit tedious but after getting used to it, it doesn't take a lot of time to build new ILS's. The main advantage of Go-Lab and ILS's is that students can work on their own, without depending on the teacher, and without just having to watch the teacher doing an experiment. Student-centred lessons engage students more and deepens their knowledge. I also use ILS's as homework for my students, so they can get deeper into topics they have talked about in their lessons and also so they can have their private workspace and enough time to try out everything on their own without being disturbed. I also really like the possibility to use external labs, for example, of the University of München. I integrate those external labs into ILS's and I use the information the University of München gives for each experiment as well as information I find while doing my own research to build ILS's.

b. Do you exchange ILS's with your colleagues or publish them on golabz.eu?

No, I like to keep the ILS's to myself so I don't have to be too conscious about their content.

c. How often do you use ILS's in your classes? When and why do you use them (instead of having a "traditional lesson"?

Most of the time, I use easy ILS's that focus on the experiment, without too much information and additional tasks, in my middle and upper level classes. Experimenting with real material will always be the best for my students, but often schools do not have enough material or material at all. Also, experiments might be too complicated or dangerous or costly to conduct them with 25 students in class. For example, the Wind Tunnel Lab on golabz.eu represents an experiment that is really important for students but almost impossible to conduct as a real experiment at school. Therefore, he uses the existing remote lab. He has used this specific lab even three times by now.

d. Preparation: Do you talk with your students about the topic and the ILS before using the ILS in class?

Before using an ILS in my classes, I introduce the main topic to my students so they know what the lesson and the ILS will be about, and then I integrate a lab or an ILS into the topic.

4. **Implementation of ILS's in class: Now, please think about one of your implementations and answer the following questions according to this implementation.**

   a. **Which ILS did you use and why did you choose it?**

For this specific implementation, I used the Wind Tunnel lab, integrated in an ILS. Before using it, I talked with my students about methods to gain data on this experiment and I even shown one of the methods in class as a teacher experiment, so the students knew how to handle the experiment. But because of a lack of material to let my students conduct the experiment at home, I used the ILS instead, so they were able to try it out themselves and gain their own insights.

   b. **Did you build the ILS yourself or did you use an already existing one that you adapted?**

I have built the ILS myself so it would fit to my lesson and students and to be able to add additional information.

   c. **How did the implementation in your class go?**

The outcome of class has been very good, students worked very well and seemed to be really engaged in the topic. Of course, there have been a few minor problems like a broken computer, but me and my students have been able to fix it and they did very well. I also liked that I just had to distribute the link, so some students even worked with the ILS on their smartphones at home.

      i. **What was the duration of usage of the ILS?**

Because I used the ILS as homework, it might have taken students around two hours to work with the ILS and present their outcomes during the next lesson.

      ii. **How did the students work with the ILS (in groups, alone…)?**

Students have been working with the ILS at home on their own. Because experiments for students are very costly and time-consuming, it is better to use labs so you don't have to prepare an experiment and then clean everything and remove the material. Also, online-labs let you control almost all possible factors of influence and you can hardly destroy them, at least as a student.

      iii. **Have there been any problems? Were you able to find a solution? How?**

The students reported no problems other than the broken computer.

      iv. **What did the students learn?**

Students reported very good results which is really important. Also, they have learned a lot about experimenting with this kind of topic in general, because if it had not been for Go-Lab, they would not have been able to conduct the experiment.

      v. **What opinions did the students have? Did they find anything especially negative or positive? Did they say something to using ILS's in general?**

Students were in a really good mood and said they would work with an ILS and conduct experiments with labs again at any time. Still, I have had a few students not participating at all, but I think with the help of ILS's, I am able to reach a few more students than with traditional lessons. The students I experienced as open-minded and enthusiastic were thrilled.

vi. **Did the students have fun?**

As far as I can say and concerning students' results and mood, they seemed to have a lot of fun using an ILS and being able to conduct the experiment themselves.

vii. **Did any problems occur on side of the students, for example, did you have to explain more things than usual?**

No.

viii. **Could you see any positive effects for the students after using the ILS (memorizing the subject matter, increased problem solving skills, working better on their own, using a scientific approach for other problems…)?**

As mentioned above, I think that just the possibility to experiment with things they would not be able to in class has a lot of benefits for students.

5. **Follow-up: What do you do after using an ILS in class?**

   a. **Do you talk with your students about the implementation afterwards?**

I always talk with my students about the results of their work with the ILS's, but I rather not do it about the usage of ILS itself, except if they have any questions. Otherwise, it is just part of the lesson and it does not need any further explanation.

   b. **Do you have a look at your students' learning outcome (the artefacts)? Where (using the Vault vs. having the students upload or send him something)? Afterwards or during the usage, for example, with the help of certain apps?**

No, I usually just traditionally talk with my students about their results and have them present their outcomes.

   c. **Can you draw any conclusions from the different learning outcome of your students (for example, concerning their quality, what has been learned and understood, focusing on a topic…)?**

Yes, in general I think that I can see which student has understood the experiment and which student did not, but it is rather not possible to differentiate between a better and worse outcome and draw the conclusion that the respective student must be better or worse than others.

6. **LA-apps: In the Go-Lab repository, there are some apps that help teachers with looking at their students' learning outcome and artefacts.**

   a. **Have you ever used one of those apps? Which ones (e.g., Action Statistics, Concept Cloud…)? How and when?**

I am not interested in the time a student needs to work with the ILS. I do not want any "surveillance", especially electronic. I just want my students to be able to upload their results.

b. Do you have any functionality in mind that might be of help for your and that does not already exist as an app?

For me, it is enough to just have a look at my students' learning outcome, I don't even have to download it. I like tools where students can enter their results and then compare their own results to the results of others. Still, it would be very helpful for me to either have some kind of "gallery-tool", where all artefacts of all students are shown, or a "portfolio-tool", where every artefact is shown for one student and you can skip between the students.

7. Will you be further using ILS's and will you be promoting them to your colleagues?

Yes, right now I am planning on using the Wind Tunnel for another lesson and I will promote Go-Lab to my new colleagues.

8. Do you have any further improvement suggestions for Go-Lab?

I really like Graasp and the way I can easily build ILS's. I am able to make my preparation and the follow-up completely in Graasp itself, which I really like. Still, even though it is easy for me to integrate external labs, I would like to have more technical labs in Go-Lab (such as the ones the University of München offers). However, one lab which I really like is the Electrical Circuit Lab. Sometimes, I would wish for more tooltips or tutorials for the labs, so the students could use them more easily.

Case Study: Rüdiger Weiß

This interview has been reconstructed from a telephone interview.

1. Background Information on Rüdiger Weiß

- Name your school and the city you work in: Wilhelm-Busch-Gymnasium, Stadthagen
- What subjects do you teach? Physics
- How old are your students? 13-18+ years old

2. Usage of Go-Lab

a. When and how did you get in contact with Go-Lab?

He has come across a Go-Lab contest 2 years ago on the internet. He sent in a suggestion for a lesson design, won, and participated in the summer school in Greece.

b. What was crucial for you to start integrating ILS into your lessons?

He really like the possibilities of Go-Lab because using it he is able to extend his usual lessons and to integrate more experiments than usually possible.

c. Have you been able to get your colleagues into using Go-Lab?

He has been promoting Go-Lab to his colleagues but, unfortunately, due to lack of time and a lot of work, none of them has used it yet. But now that he sees all the improvements in Go-Lab, he thinks that he might want to try again and engage other teachers as well.

3. Building and adapting of ILS's

a. Do you build your own ILS's on Graasp or do you adapt already existing ones? Why?

In my language learning class that consists of very different students of different ages and from all over the world (a lot of refugees) where I have used an already existing ILS. But because Graasp now has the new design, I might also want to build my own ILS's.

b. Do you exchange ILS's with your colleagues or publish them on golabz.eu?

I would like to do both, sharing ILS's with his colleagues as well as publishing my own ILS's on golabz.eu.

c. How often do you use ILS's in your classes? When and why do you use them (instead of having a "traditional lesson"?

I use ILS's to introduce my students to new topics as well as deepening their knowledge on topics they are already familiar with. Mostly, I like the physical experiments. Usually, I prefer real experiments in class, but if the school lacks the material or the money and possibility to buy things for experiments, it is a nice thing to use Online-Labs instead. I really like the PHED Labs and sometimes I even use only a lab in my class and let students present their results in class afterwards.

d. Preparation: Do you talk with your students about the topic and the ILS before using the ILS in class?

I simply showed them the ILS in class and how to use it, so they could afterwards simply experience using it themselves. For example, experiments about wavelength would not be possible if not for the help of Online-Experiments, where you can also zoom in and out, or slow down or speed up the process.

4. Implementation of ILS's in class: Now, please think about one of your implementations and answer the following questions according to this implementation.

a. Which ILS did you use and why did you choose it?

I have used a lab about the photoelectric effect and one about laser, because they simply fit to my lessons. In my language learning class, I have used the Gear ILS even in English, because that is one of the languages all of those students understand.

b. Did you build the ILS yourself or did you use an already existing one that you adapted?

I just took the already existing Gears ILS.

c. How did the implementation in your class go?

In his language learning class, I just let students find their way through the ILS. They could choose whether they wanted to work alone or together with another student, because they were of very different ages and had very differing knowledge. They could work in their own tempo and he just walked around and helped the students that needed guidance.

i. **What was the duration of usage of the ILS?**

1 didactic hour.

ii. **How did the students work with the ILS (in groups, alone...)?**

Both (as mentioned above).

iii. **Have there been any problems? Were you able to find a solution? How?**

Some of the students were not able to figure out how to compose the gears, but I liked that the ILS had an introductory video, a hypotheses phase, and then focused on the experiment. I would have liked to have some more explanation on how to use everything for the students, though.

iv. **What did the students learn?**

It was just a fun experience for them and most of them had never used such Online-Experiments before.

v. **What opinions did the students have? Did they find anything especially negative or positive? Did they say something to using ILS's in general?**

There have not been many comments on the usage of the ILS, but they seemed to like it and were quite into it.

vi. **Did the students have fun?**

Yes, of course, most of these special students usually don't have the opportunity to work on something like this themselves and be able to figure out an experiment.

vii. **Did any problems occur on side of the students, for example, did you have to explain more things than usual?**

No.

viii. **Could you see any positive effects for the students after using the ILS (memorising the subject matter, increased problem solving skills, working better on their own, using a scientific approach for other problems…)?**

Even though I usually think that it might be possible to see positive effects of the usage of such an ILS, it is hardly possible to evaluate the students of the special class because he just started working with them in February and he used the ILS so they had something to work with.

5. **Follow-up: What do you do after using an ILS in class?**
   a. **Do you talk with your students about the implementation afterwards?**

Yes, usually I would.

   b. **Do you have a look at your students' learning outcome (the artefacts)? Where (using the Vault vs. having the students upload or send him something)? Afterwards or during the usage, for example, with the help of certain apps?**

In this special case, I did not look at the outcome, but usually it would be of interest.

c. **Can you draw any conclusions from the different learning outcome of your students (for example, concerning their quality, what has been learned and understood, focusing on a topic…)?**

I might do this in the future.

6. **LA-Apps: In the Go-Lab repository, there are some apps that help teachers with looking at their students' learning outcome and artefacts.**
   a. **Have you ever used one of those apps? Which ones (e.g., Action Statistics, Concept Cloud...)? How and when?**

Yes, I have had a look at the apps and I might use them in the future because they look quite helpful and offer a lot of possibilities.

b. **Do you have any functionality in mind that might be of help for your and that does not already exist as an app?**

For me, a "gallery-tool", where all artefacts of all students are shown, or a "portfolio-tool", where every artefact is shown for one student and you can skip between the students, would both come very handy.

7. **Will you be further using ILS's and will you be promoting them to your colleagues?**

Yes, I think so and I might even try to engage my colleagues again.

8. **Do you have further improvement suggestions for Go-Lab?**

No.

Case study #4: Sören Werneburg

This interview has been conducted by Kristina Angenendt, at the Otto-Hahn-Gymnasium in Dinslaken, with Sören Werneburg Interviewer: Kristina; Teacher: Sören Werneburg

1. Background information

a. **So, you teach Mathematics and Computer Science.**

That's right.

b. **Both middle and higher classes (German: Sekundarstufen 1 and 2)?**

Yes, both.

c. **Have you been using Online-Learning Environments before you started using Go-Lab?**

No, not at all.

2. Go-Lab in general

a. **Okay. So, when and how did you get in contact with Go-Lab?**

When Sven Manske of the University of Duisburg-Essen conducted several Go-Lab studies, he got in contact with me and asked me whether I wanted to participate. It might have been two or three years ago. Yes, the first study has been the one with the Osmosis Power Plant, together with Adam Giemza, and of course I wanted to participate!!

b. And did Go-Lab change your approach to experimenting itself? Like, do you like using specific things better than others?

The thing is, it is very difficult to experiment in Mathematics or Computer Science because you don't have any existing experiments. The best thing is that you can come up with experiments yourself that are computer supported, that you can integrate in this environment, so you can work more effectively with general digital tools.

c. Especially in Computer Science?

Yes, but also in Mathematics. You can integrate GeoGebra for example, which I think it is a really good thing. Using GeoGebra alone is too plain, but if you integrate it in a learning environment, it has a completely different feeling to it and personally, I like it way more, because then it counts as or can even replace a whole lesson.

d. Oh yes, you have uploaded one of your ILS's that uses GeoGebra, right?

Yes.

e. Do you know any other teachers that are working with Go-Lab?

Maria Frank (laughs). But no one else… Most of the colleagues I have invited just see Go-Lab as additional work…

f. Do you exchange things like ILS's etc. with Maria?

Well, when we were in Greece, we have been working on several things and there we have exchanged experiences, especially how to best use the platform, using different tools, but we do not really exchange ILS's, rather "how do you best use x-y". And that's the most fun thing, building your own ILS's!

g. Like exchanging best practices for Graasp…

Yes.

h. And golabz.eu, do you still use this page? For example, for finding new stuff or looking things up?

The thing is, golabz.eu is rather suitable for other teachers, biologist or physicists, and sometimes I still have a look at it but…for me, there are not so many labs which I can use…

i. Other teachers have told me that they sometimes use labs for example from the University of München, have you tried integrating other external labs yet?

Yes, and that is the good thing! No matter what you need, you can integrate anything. And that is a big advantage that I have not seen in other learning environments and I really like that you are not only able to use only the Go-Lab labs but other labs as well!

3. Working with Graasp: Building and implementing ILS's

a. at is very handy! And if you think of the usage of Graasp itself, when you started working with it, how difficult did you find the system?

That was horrible because it was still the orange system…

b. The older version of Graasp.

(laughs) And then, the new, blue environment came and everything was suddenly very easy to use. Of course, there are still a few things that are not 100% intuitive but after clicking a few times, you usually are content with what you did, and this way you can work with it very well! And with the additional students' view (the distribution link view) you can always see what it looks like right now. Also, the environment in Graasp is a kind of "what you see is what you get", because if you fill an ILS with things, it will almost identically look like that. That is very nice as well, you can work with that very well.

c. So you would say that right now it takes you less time to build an ILS then at the beginning?

No, it's way faster by now! At first, I didn't even understand how to work with it, I wasn't even able to build a single ILS, I had to find out where to click first and then it still didn't work (laughs). But now, yes, it is really easy to build an ILS.

d. How long does it take you to build an ILS from scratch?

That depends on the ILS… If you build a new lab as well, for example, GeoGebra that might take you a while, but you would make this effort anyway…

e. And building your own lab definitely counts as expert mode!

To find additional texts or videos and add them to your ILS, if you already have an idea, you can be done with it within half an hour. You don't even have to worry too much about the design because you don't have that many possibilities to change it (laughs). And that's a good thing as well! Because you do not have so many ways to change the look of the ILS and because it already looks nice anyway, you can work on it very easily. Also, the design of the learning environment should not distract the students from the content of the ILS, you should keep that in mind! That's why you don't need it, it has a decent design and that's it.

f. Yes, I think that was the idea when setting up the new Graasp. So, do you rather build your own ILS's or have you also used already existing ones and adapted them?

Of course I have also been adapting already existing ones, for example, the encryption ILS, I could perfectly use that for my Computer Science class. And there, everything was already there and I didn't have to change much, so the "building" took me only a second. And that was very nice, one click and I had an existing lesson.

g. Yes, the encryption ILS has now been published in German to golabz.eu as well. But you have already shared a space with Maria, didn't you? And published your own ILS.

Yes, I did.

So, if you have built an ILS, you might have an idea when and how to use it in class? What would be the crucial thing for you to say that you will use an ILS and an experiment for topic xy instead of having a traditional lesson?

The advantage is, students approach the tasks autonomously, and that is a really important competence they have to learn: to work independently, to consider different possibilities, to search on the internet and to look up things, find their own way. There is just a little guidance, of course it takes more time than a traditional lesson but they memorize it better. For example, a short time ago, I have talked with my students about the osmosis study and they still knew exactly what it was about. Because they have been working with it for a longer time than they would have done if I had just shown them how it worked. Casear's encryption as well, my Computer Science students still knew everything, because they have been experimenting with the Caesar's wheel and have been applying the Vigenère's alphabet instead of just looking at it, and this way they had the possibility to discover the topics themselves, which takes more time but they also get more into it. Also, they always kept problem solving in mind which kind of motivated them. And that of course helps them to internalize things.

h. **The application of the theory, yes. Have you also used ILS's or labs as homework? Some teachers told me that they want their students to work with the topic at home.**

Nooope! (both laugh) But that's because if I make a huge effort, then I also want my reward by having a nice lesson (laughs). No, I don't make such an effort for homework, then I'll just tell them "book, page 17".

i. **And then the students have all the work on their own at home (both laugh). So, you can't really do real experiments in Math or Computer Science right? Biology teachers have been telling me that sometimes they like a virtual lab more because there they can zoom in and out, slow down or speed up processes… that's handier to them than just doing a teacher experiment and letting the students watch.**

Yes, for example, the preparation time is decreased. If I think of the encryption ILS, when I make my older students craft the Caesar's wheel first, they are just unchallenged and it takes a lot of time, so this is a big advantage too. You don't need any time for preparation or a follow-up, for example, cleaning up and putting away instruments and stuff, that's a huge advantage.

j. **If you say you don't need any preparation time, or crafting time for the students, do you still prepare your students by saying „next lesson, we will do an online activity and it will look that way and that way" or do you just provide them with the ILS?**

That depends on several things. Do I already know that I will use an Online-Experiment in the next lesson? If I am going to prepare an ILS, I might do it over the weekend… Sometimes I get the idea "hey, I can also use an ILS for that!" and maybe I didn't know that a lesson ago. But of course, sometimes I tell them, but I don't necessarily inform them.

k. **Okay, and what is their reaction when you provide them with an ILS, is it still something new for them?**

Well, classes that already know ILS's in general won't be surprised anymore. Every new class will be very happy to use an ILS because you'll take them to the computer room which is not a usual lesson for them and when they discover, for example, the Hypothesis Tool, they have a lot of fun clicking around. But they still learn something while doing this and they notice it themselves, so they'll say "oh okay, a usual lesson, just with an ILS". And that fits well into a normal lesson, so it's great.

- **l. That's cool if your students think that it is quite normal to use an ILS and nothing special anymore.**

Yes, you get that a lot, especially when taking them to the computer room, "oh that's going to be fun" and then there is no real outcome. And that's what I got when we went to the computer room for GeoGebra only, they didn't really take it seriously, it was just some stand-alone thing they could fool around with, but they didn't really accomplish their actual tasks or they would work very slowly. Because of the guidance of an ILS they are actually working towards a goal so I think it has really positive effects.

- **j. So you mean, the task is clearer if they use an ILS instead of just a lab, they benefit from a better guidance?**

Yes.

- **k. Some teachers told me that they like using only labs because then they feel like they are able to give the students different tasks…**

Of course, it is more individual, because you can react better to a student who doesn't understand something at one point, he might be trapped at this point if he was working with an ILS. But I think that an ILS gives you some kind of starting structure, because it is more project-oriented and closed because it contains additional information and that's what I like better. Of course, it is easier if you do not have to search for additional texts and videos, but I think, there are advantages and disadvantages to both.

- **l. Do you plan rather bigger ILS's, adding videos and audio files and other stuff, or do you also use those kind of micro ILS's, maybe consisting of three pages and one experiment?**

Rather bigger ILS's. They are supposed to take a couple of hours so the students realize that it is a lesson that should have an outcome and is not just something to play with. That's my aspiration at least.

- **m. So it is supposed to take them a few hours, like two or three?**

Yes.

4. Follow-Up: Learning Analytics Apps

- **a. And when they are done with the ILS, there a tools that can show you all kinds of learning products, how do you precede afterwards?**

Well, I am still missing the most important thing, an app that gathers all results to some kind of blackboard picture or a poster that would be perfect. I myself do not use tools like diagnostic tools and so on, I walk through the class and observe how they are working, I do not need to analyse graphics. But what happens is that they need to somehow collect their results and take them with them out of the class.

b. **You rather observe the learning process from the outside than following it with the help of an app?**

Yes, I do not use an app, they can rather document their process themselves, for example, making a poster which you can use afterwards to work with. You shut down the computer and they still need something to take with them, that's very important for me to guarantee that. Then, the lesson is closed.

c. **Would you rather have a tool that shows you all of the artefacts per student or one that shows you for example all of the wiki articles of all the students?**

The question is, with wiki articles, it might be a huge poster with way too much content. But in general, especially mind maps or concept maps that are displayed, that might be a big advantage. Or that you can say “take the picture of this student and the wiki article of this student”, and then those things are distributed on a poster… both might be handy.

d. **So both for one students and for all students**

Yes, so every student has something for themselves, and if you see that there might be some good artefacts, you can just collect them and display it together. I'll take the text from student 1, the hypothesis from student 2, and then you would have some artefacts. You would click on enter and some picture or poster is produced. That would be best.

e. **Yes. Should the students be able to see it as well, for example, to compare themselves to others or look up what other students have been doing?**

No. For them, it might be useful to have a button that says “collect those things and build a poster“ of their own things, but the actual result in the end should be controlled by the teacher. I think that is important because students can hardly decide what is good and what is not.

f. **Yes, that's true.**

Of course you can train them to being able to do that but the question is if that's the right situation. And I think every student wants their privacy at the computer.

5. **The students' opinions**

a. **Yes, you are right. But after an ILS usage, have you been talking with your students about it, did they have any questions, for example, if it was a new experiment for them, and that they wanted to know what exactly they had been doing there?**

Well, they really wanted to talk about what they had been using the ILS for (laughs). And then I explained to them why we had been doing it in this way, because they said that it takes a lot of time, but they also saw that they did understand the topic better. We did some repetition lessons and I said “hey, you know so much” and then I tried to explain it to them, and I said “but maybe it's just because you are so smart” (laughs).

b. **Oh yes, that's possible, they are just the smartest class (both laugh). So you have been doing more than one ILS with the same class, right? Have they asked you yet if you could just give them an ILS for an upcoming topic instead of working with it in traditional lessons?**

No.

c. **They did not feel like it yet?**

They rather wanted the traditional lesson because the advantage is, they just sit there and don't have to do anything. They just sit there and absorb stuff and apply things they have to apply and that's it, that's way easier.

d. **Okay. And if you have a look at the students' learning products afterwards, do you think you can draw some conclusions considering the learning quality or of their understanding of the topic?**

Yes, you can tell by their way of writing the texts. For example, in the Wiki-Tool, that's also a big advantage: you don't have to collect their results, they are just saved in the Vault and I can click through them and I can read it over and over, depending on how the text is written, but that's normal. This way you always see whether they have understood something or not. Because they are forced to write something you actually get results. And they are just there, that's good!

e. **Could you make use of a printing function to print out the student' outcome? If you say your students need something to take with them after the lesson...**

Well yes, I mean, an app where students can submit their results, that's something I need. And afterwards, you can print them and then you're done.

6. Remembering a specific implementation

a. **Yes, that sounds useful. Now we get to the point where you are supposed to think of one of your implementations in particular. Do you have something in mind right now?**

Yes, let's take the Erastosthenes ILS. It's about the length of shadows. (http://www.golabz.eu/lab/sun-shadow-visualizer).

b. **Okay. Did you built it yourself or did you adapt an already existing one?**

I have built it myself.

c. **Okay. But why? Wasn't there an already existing ILS?**

No, there wasn't. And second, I could use GeoGebra that was my first try to work with GeoGebra and an ILS so, yes. That was my motivation, there was no existing ILS with GeoGebra yet and I wanted to see how well I could handle it if I would try to implement mathematical topics.

d. **So, how was the ILS constructed? What did it contain?**

It was about shadows. The mathematical topic was the intercept theorem and the students were to understand the topic. So I motivated them by using shadows and showing them a video on the experiment of Erastosthenes who measured the perimeter of the earth using shadows. And of course they had to learn something in general about shadows und about how shadows change depending on the sun. Then it got more mathematical: they had to compare shadows, use the intercept theorem, equations, and they had to do some calculations, that was awesome (laughs).

e. **(laughs) Very nice! How long did the implementation take?**

It took about two didactic hours in class. But that's because it wasn't just about the mathematical terms and their discovery but also about the history around that, how they developed the theory 3000 years ago.

f. **And was that a new topic for your students or rather an addition to something you have been doing before?**

The mathematical matter was new for them, so it really was inquiry learning in those lessons and for this topic.

g. **Have there been any problems, for example, technical ones, or did you have to interfere or explain things.**

Well, that's always a problem in a computer room when ten or 20 groups are supposed to watch a video… (laughs)

h. **Yes, that's true. You might have to use headphones.**

Yes, but also the streaming rates. You may not forget that it is always a bit difficult, but otherwise, there were no problems. The app worked perfectly, they could navigate through the ILS, and everything was okay.

i. **Have you been talking about the usage afterwards, maybe discussing results or something?**

Yes, first, we had some kind of two-sided discussion: One the one side, about this really big context of the mathematical problem, we talked about why they did what they did in the old times, but also about the way to make it a mathematical problem. They had made their discoveries and had been describing them, and they started developing first ideas of how to build formulas for the problem, but they still had to abstract it somehow, to be able to use it for future problems as well. In this special case, they did perfectly well and had already been finding patterns, but especially in lower classes (German: Sekundarstufe 1) you have to help them take the last step, and that is drawing conclusions from your observations.

j. **Okay. And have you been able to see any positive aspects for the students, maybe you were able to compare them to another class that had not been using an ILS to work with the topic, so you could say one class did better than the other?**

My opinion is that because of the experiment, they approached the calculation a lot more intuitively, because they didn't just have to image those four crossed lines but they were thinking within those ratios and were trying to transfer that, one thing is small, one is big, and there is some similarity between the figures. They have been trying to work a lot more application-oriented, not just based on formulas. I think that was a big advantage!

k. **And what did the students say? Has it been the first ILS this specific class has been working with?**

Yes, it was. Well, they found it very cool to watch a video in class (both laugh). Yes, I think they found it very cool. Because it wasn't just calculating in class, there was some change in the lesson, they really liked it.

l. **Have they been fooling around as well?**

No, I am a good teacher. (laughs)

m. **That's right (laughs)**

(laughs) No but they didn't. Because they have already been focused on the ILS, they had to handle the sliders, adjust everything, and make their observations, measure things, it was really funny when they started holding the ruler in front of the computer. (laughs)

n. **That sounds like a lot of fun! But did you have to help certain students more than others, for example, explaining more things in the ILS?**

Well, I can't remember… I think, a lot has been quite intuitive. So it went quite well. Because they were able to try things out in their ILS, they could not do anything "wrong".

o. **Have you ever observed students helping each other while using an ILS, like when one student can't figure out what to do next?**

Yes! They always say "how do you do xy? ", "well, you have to do that and that". That's standard, you always have that.

p. **And with this implementation, has there been something especially negative or positive?**

The positive thing is that the students approached the ILS with such a curiosity, because they didn't have the feeling anymore that they were "just doing math" but prior to it, they had to discover everything and try it out themselves. And because of that, there was a lot of positive motivation from the students. And that kept on going through the whole working process with the ILS, because somehow they just wanted to understand everything that was displayed.

q. **That is really nice because especially in school, most of the time you are not that interested in the topics because you always have the feeling that you'll have to learn that anyway.**

Yes, just like that!

7. **Feedback on Go-Lab**

a. **Will you be using ILS's in the future?**

Of course! (laughs)

b. **And your colleagues, I mean, if they say that it is too much an effort for them.**

Well, you have so many duties and then you ask yourself "do I really want additional work?" And the answers is no. Don't change a running system.

c. **We always try to explain to new teachers that, like you said, once you got into it, it is not such big an effort anymore. But getting into it, well… But do you have any additional suggestions to improve Go-Lab?**

I have already mentioned a few (laughs). The most important thing is that because the students will leave the class without anything in their hands, you need some kind of learning product as a result, otherwise it will always be difficult for them to handle the knowledge they gathered in an ILS.

d. **That's true. Are there any labs or ILS's for specific topics that you might wish for?**

The advantage is that you can easily integrate anything or even build your own stuff if you feel like it, so you have a lot of freedom to do whatever you want, so right now, I cannot imagine any specific thing I might wish for.

e. **Okay, then this is it! Thanks for doing this interview with me and giving me insight in your work with Go-Lab!**

You are welcome!

4.2.4.3.1 Conclusions

Advantages of using Go-Lab tools

- Many advantages of using both ILS and labs were mentioned. Among them, and in reference to ILSs, is the possibility to combine different sources and tools in a same space.
- Moreover, ILSs are very helpful tools as they provide with easy to navigate learning environments which focus on the lab itself rather than providing students with too much information at once. Also, by building your own ILS, you are able to ensure the content fits your lesson plan.
- ILS's are also useful to introduce students to new topics as well as to deepen their knowledge on topics they are already familiar with as well as to allow educators to develop student-centred lessons.
- With the ILS, teachers are able to ensure they can reach more students than without it. Also, while only using labs makes work more individual with each student, ILSs give some kind of starting structure, as it is more project-oriented and closed and because it contains additional information.
- Yet another main advantage of the ILS is that of being able to create your own when there is no material available.
- Nonetheless, the possibility to use external labs can help integrate those external labs into ILS's and use the information the organizer gives for each experiment as well as information the educator can find while doing own research to build an ILS's.
- External labs are a great resource as, even though experimenting with real material will always be the best for students, often schools do not have enough material or material at all.
- The possibility to experiment with things they would not be able to in class has a lot of benefits for students. In fact, it is difficult to experiment in subjects such as Mathematics or

Computer Science because of a lack of any existing experiments. However, one can come up with experiments that are computer supported, which enables students to work more effectively with general digital tools.

- A big advantage not usually seen in other learning environments is the fact that you are not only able to use only the Go-Lab labs but other labs as well.

Disadvantages of using Go-Lab tools

- Problematic situations can arise if teachers are already used to working with their own platform (e.g. Moodle) as it is therefore not easy to establish a new platform and to make teachers use it. It would be good if resources from other platforms could be integrated in an easier way.
- For educators already acquainted with Go-Lab, the non-existence of ILS with specific software (e.g. GeoGebra) can prompt then to create ILSs incorporating them and how can they work within the Go-Lab platform.

Classroom implementation

- In general, while students' performance was good and the possibility to work from home was very welcomed, sometimes technical problems could be a burden.
- In general, it is quite positive that through the use of Go-Lab resources, students can learn to operate and work independently.
- In some cases, teachers find it useful to use ILS's that focus on an experiment, without too much information and additional tasks, to simplify its execution.
- Nonetheless, the ILS guidance is crucial as students are actually working towards a goal and it usually has really positive effects. Also, ILS can fit very well in a "normal" lesson.
- In general, educators did not feel the need to talk about the usage of the ILS itself with students. They would only use it as an extra tool in the class.

Potential extra features for the project:

- For some teachers, it would be helpful to either have some kind of "gallery-tool", where all students' artefacts were shown, or a "portfolio-tool", where every artefact would be shown for one student and teachers could skip between each students' work.
- Potential additional apps to use in Go-Lab could involve mind maps or concept maps, or even a gallery of students' resources, so they could all be gathered in a same space. Also, any app related to something that would help classify students' results would be helpful. Translation resources are also generally needed, unless the teacher modifies the ILS him/herself.
- As other general suggestion to improve Go-Lab is the possibility of giving students a final product. Since they will leave the class without anything in their hands, it would be useful to have some kind of learning product. Otherwise it will always be difficult for them to handle the knowledge they gathered in an ILS.
- In regard to students' responses, they generally considered it was just a fun experience for them as most of them had never used such online experiments before.

- Some students also considered the ILS to take a lot of time. However, they also stated that they did understand the topic better after going through the ILS process.

Teachers' engagement in Go-Lab:

- Some teachers have promoted Go-Lab ILS's without much success. More efforts in that regard are needed. On the same topic, most teachers who became acquainted with the Go-Lab did so through workshops or other events. In general, one of the main challenged to convince colleagues to use Go-Lab only regard it as additional work

4.2.4.4 Italy (2)

Research themes/questions:

1. Background information about you, your school and students that participated in Go-Lab
2. Why did you choose the specific laboratory/ILS?
3. Did you have to adapt the ILS in any way? If yes, what did you do?
4. How did the implementation of the ILS go within your classroom?
5. How did the students behave during the whole process and what did they learn?
6. What was good about the ILS and what were the drawbacks?
7. Would you do it again and would you recommend it to your colleagues?

Case Study #1: Federica Biglino

Your Name: Federica Biglino	**School:** IC Varazze - Celle	**ILS/laboratory used:** La material, il calore e I passaggi di stato http://graasp.eu/ils/56716fdb84f279b7b2c428ad/?lang=it	**Date:** November 2015
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
19. Background details about: 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity 1c. Any contact with representatives of organisations who created this laboratory/ILS	☐Video/audio recording of you talking about the background details ☐Text ☐Will discuss in a follow-up telephone call		(e.g. Audio file attached “sample.mp3”) I’m a teacher of STEM in a middle school in Italy, I’m postgraduate in ocean environment sciences and I teach math, geometry and general sciences. The pupils for this ILS are 11 and the class was their first class in a middle school.
20. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording ☐Text Will discuss in a follow-up telephone call		I chose these labs because they are easy to understand and use and they explain very well the matter property.
21. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students’ behaviour and response to the practice	☐Video recording during the activity in your class ☐Photos capturing the key moments of the practice ☐Written description of the process		Students are really involved into the ILS they found interesting and enjoyable learning by doing and using different kind of apps. It was useful the mind map app and the observation tool because pupils have to argue their thought, one of the goal of the Italian education curriculum.

Your Name: Federica Biglino	**School:** IC Varazze - Celle	**ILS/laboratory used:** La material, il calore e I passaggi di stato http://graasp.eu/ils/56716fdb84f279b7b2c428ad/?lang=it	**Date:** November 2015
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
22. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class ☐Written description of the process ☒Sample of students' work (links, pictures etc.)		
23. What was good about the ILS/laboratory you have used and what were the drawbacks?	Video/audio recording of using the activity in your class ☐Written description of the process ☒Sample of students' work (links, pictures etc.)		Good thing: - An ILS is a kind of flipped classroom tool, pupils can work at school and at home watching again and again lessons and labs. - It is a cooperative work, pupils can find helps to their

Your Name: Federica Biglino	**School:** IC Varazze - Celle	**ILS/laboratory used:** La material, il calore e I passaggi di stato http://graasp.eu/ils/56716fdb84f279b7b2c428ad/?lang=it	**Date:** November 2015
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
			peers and give yours. Drawbacks: - Project the ILS isn't easy you need to watch and listen the pupils' feedback trying to understand what works good and what not. - It's important to choose the right tools and labs. - You need good technology, Computers must be update and the Wi-Fi connection must be good or many labs and apps don't work.
24. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☐Written description of the process ☒Sample of students' work (links, pictures etc.)		Of course, that's why I made two updating course to my colleagues this year and in one of them I decided to spend a lessons for STEM teachers about Go - Lab and Graasp. They found it really interesting and useful but English, for some of them, could be a problem so I know that I have to work to translate something.

Case Study #2: Daniela Leone

Research themes/questions:

1. Background information about you, your school and the students that participated in Go-Lab

My school is named Istituto Comprensivo 9 in Bologna, Italy, and its students are from 3 to 14 years old. I have been working in lower secondary level for the last 3 years. My teaching subjects are Math and Science and I have 3 courses with about 20 to 25 students each. Most of my students were born in Italy, but many have non-Italian parents.

The school is well equipped with ICT. It is involved in many innovative educational projects and in teachers training. The school site is http://www.ic9bo.gov.it/wordpress/.

The newest activities started in 2015 when a new ICT classroom was open. In 2016 the main activities experimented in the new classroom where Go-Lab, Girls Code it Better and Flipped Classroom.

2. Why did you choose the specific laboratory/ILS?

One of the most recursive subjects in the school Science curriculum is chemistry: it has several connections between other disciplines like biology, physics, astronomy, medicine and health and geology.

In the Go-Lab site I made 2 ILSs about chemistry in Italian for my students:

http://www.golabz.eu/spaces/soluzioni-e-misura-del-ph

http://www.golabz.eu/spaces/il-linguaggio-della-chimica

The purpose of both ILSs was to help students visualize some abstract concepts and to get familiar with their symbolic representation.

3. Did you have to adapt the ILS in any way? If yes, what did you do?

The first time the ILS http://www.golabz.eu/spaces/soluzioni-e-misura-del-ph was used by students in a PC lab and at home, few of them were able to complete the whole inquiry learning cycle.

This year it was used again with new students in the new classroom and it was a test both for the classroom devices and for the ILS: the expected results and the issues reported by students were taken into account and some changes are planned. The new version is not yet completed, due to time limitations.

The planned changes are:

- HTML5 simulations, in order to run it on every device (tablets or PC)
- examples of experiments that can be done by students
- more applets in order to introduce concepts in a more gradual way (http://www.golabz.eu/lab/concentration, http://www.golabz.eu/lab/ph-scale-basics)

4. How did the implementation of the ILS go within your classroom?

Taking into account the previous test, the second ILS was implemented involving students in the design process: they tested simulations, compared them to their book's theory, asked questions, explained results, and proposed to match real experiments to virtual investigation.

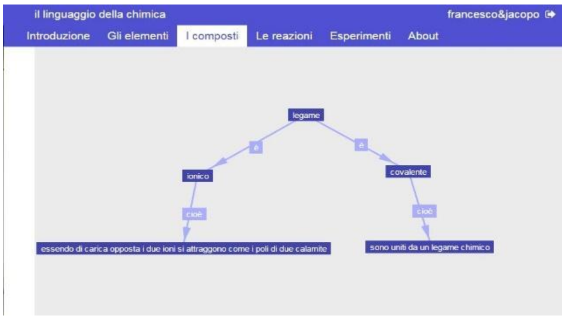
http://www.golabz.eu/spaces/il-linguaggio-della-chimica

5. How did the students behave during the whole process and what did they learn?

Students were involved both as authors and as users on the ILS, they became more motivated by adding their contributions to the implementation process. They tested the ILS before, during and after its completion.

They connected the ILS contents to other experiences they had at school, as other science labs conducted by external experts.

They could give significance to specific language and symbols and could transfer this skill to other activities.



6. What was good about the ILS and what were the drawbacks?

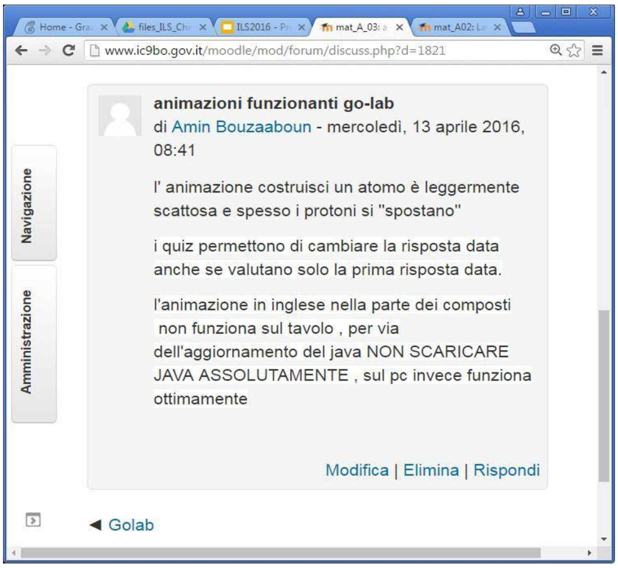
The main advantages were the increasing students' persistence in their investigation process and the increasing interest for other science activities.

Due to limited time, not all students could complete the inquiry learning cycle in the final testing phase.

Some students were more involved in the authoring phase and others gave more contribution to the testing phase.

The ILS implementation was presented to the Go-lab teacher contest 2016 and awarded with the summer school 2016.

Some apps couldn't be used in the expected way, such as chempy and quiz app.



7. Would you do it again and would you recommend it to your colleagues?

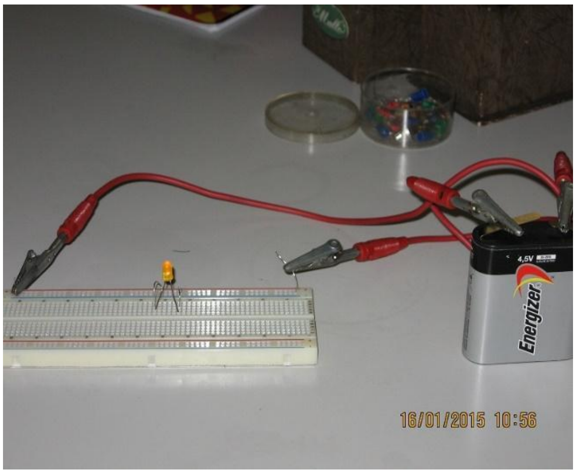
With the same students, I would like to use new labs next year, such as the electrical circuit lab (http://www.golabz.eu/lab/electrical-circuit-lab) that can be easily matched to real circuits made by students with school instrumentation.

With new students, I would like to test the previous ILSs about chemistry, applying the needed changes to the solution pH ILS.

Regarding my colleagues, I asked them to help me preparing some biology activities, since they are more experienced than me in that subject.

Some colleagues have already tried the published ILS with their students. Some are not yet confident enough with the new ICT environment and they may need some help.

It is not easy to involve colleagues in the authoring process because of their lack of time or skills or motivation, but in the teachers training plan for next year I will propose a training about Go-Lab.



Your Name: Daniela Leone	School: Il Guercino - IC9 Bologna	ILS/laboratory used: http://www.golabz.eu/spaces/il-linguaggio-della-chimica	Date: 24/06/2016
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*	**Answers (text):**	
1. **Background details about:** 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go-Lab activity 1c. Any contact with representatives of organisations who created this laboratory/ILS	X Video/audio recording of you talking about the background details X Text ☐Will discuss in a follow-up telephone call	(e.g. Audio file attached "sample.mp3") https://youtu.be/MLkbL2Yv1yc TV broadcast about the new classroom https://youtu.be/lzBq3XLUukA TV broadcast about innovation at school GO-LAB Contest 2015 entry in english	
2. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording X Text Will discuss in a follow-up telephone call	ILSs published in the GO-LAB site http://www.golabz.eu/spaces/soluzioni-e-misura-del-ph (2014) http://www.golabz.eu/spaces/il-linguaggio-della-chimica (2016) GO-LAB Contest 2016 entry in English	
3. **How did the implementation of the activity go?** 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students' behaviour and response to the practice	☐Video recording during the activity in your class X Photos capturing the key moments of the practice X Written description	Pictures included in the text description	
4. **Outcomes for students:** 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☐Video/audio recording of using the activity in your class X Written description of the process X Sample of students' work (links, pictures etc.)	Photos included in the text description	
5. **What was good about the ILS/laboratory you have used and what were the drawbacks?**	☐Video/audio recording of using the activity in your class X Written description of the process X Sample of students' work (links, pictures etc.)	Pictures included in text description students presentation of science lab	
6. **Would you do it again and would you recommend it to your colleagues?**	☐Video/audio recording of using the activity in your class X Written description of the process X Sample of students' work (links, pictures etc.)	Pictures included in text description	

4.2.4.4.1 Conclusions

- In relation to already existing ILSs, the preferred ones are those that are easy for students to understand.
- The fact that ILSs can be used as flipped classroom tools was considered as a main advantage. Thus, ILSs can also be used by the students at home and can be incorporated as homework. Moreover, it allows teachers to cooperate easily with pupils.
- As limitations of the ILS's, some apps could not be used properly during its implementation and adequate technological devices are necessary throughout the whole process, which might not always be easy. Language barriers can also be an impediment.
- Students' feedback remained positive. Students liked the fact that they could use different apps. Moreover, it was reported that the the use of Go-Lab tools helped increase students' persistence in their investigation process as well as in their interest for other science activities.
- In one case, students were also involved in the design process, both as authors and users. One of the ILS's was used with different groups of students as a way to adapt it to their needs and in order for them to be able to complete the whole inquiry cycle. In particular, students were able to test simulations, compare them to their book's theory, ask questions, explain results, and propose to match real experiments to virtual investigation.

  In terms of dissemination, reaching others colleagues still proves to be a challenge: In particular, some of them still need to be more confident in using specific technology devices and software. Moreover, they can lack skills, motivation or be limited due to time-constrictions.

4.2.4.5 Spain (1)

Research themes/questions:

1. Background information about you, your school and students that participated in Go-Lab
2. Why did you choose the specific laboratory/ILS?
3. Did you have to adapt the ILS in any way? If yes, what did you do?
4. How did the implementation of the ILS go within your classroom?
5. How did the students behave during the whole process and what did they learn?
6. What was good about the ILS and what were the drawbacks?
7. Would you do it again and would you recommend it to your colleagues?

Case study #1: Pilar Gonzalez Sanchez

Your Name: Pilar Gonzalez Sanchez	**School:** Institut de Begues	**ILS/laboratory used:** ● ¿Es la radioactividad perjudicial para los humanos? / Radioactivity ● "¿De qué está hecho?" / Density and buoyancy ● "Principio de Arquímedes (I)" / Archimedes Lab Deusto.	**Date:** 29/06/2016

Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*	**Answers (text):**
25. Background details about 1a. Your teaching background, your school and your students 1b. Other staff members in your school involved in the Go Lab activity 1c. Any contact with representatives of organisations who created this laboratory/ILS	☐Video/audio recording of you talking about the background details ☒Text ☐Will discuss in a follow-up telephone call	Science teacher in Institut de Begues, a high school near Barcelona. It's a small school, with only about 200 students. My students are from 2 different levels: some are 13-14 years old, the others are 14-15 years old. A colleague from the Science department (Silvia Gimeno) introduced the Go-lab project in our school the year before. This school year she has had time problems to use it. I have been in contact with Javier Garcia-Zubia and his team, from the Deusto University, to arrange the use of the Archimedes remote lab.
26. Why did you choose this laboratory/ILS? 2a. Did you have to adapt the ILS in any way? 2b. If yes, what did you do and how?	☐Video/audio recording ☒Text Will discuss in a follow-up telephone call	The ILS were chosen because they fit with the curriculum and they were of the correct level to use with my students. Two of the three ILS used were adapted from the original ones from the golabz.eu resources. Originally they were in English so I translated them into Spanish and I also incorporated subtitles in some of the videos used. The third ILS was made by myself, in Spanish, to use it with my students.
27. How did the implementation of the activity go? 3a. The actual process of using the Go-Lab ILS/laboratory in your classroom 3b. Students' behaviour and response to the Practice	☐Video recording during the activity in your class ☒Photos capturing the key moments of the practice ☒Written description of the process	You can find the process followed in the following link (poster): http://bit.ly/GoLabPoster2016 It summarizes all what I have done. Basically, the process consisted in a first description in the classroom with all the students, then if it was possible, they started the activity in the classroom and then finish it in their home, send me a final report. You can watch some photos in the same poster or in this link. http://bit.ly/GoLabFotos2016
28. Outcomes for students: 4a. Students talking about their experience and if they have enjoyed the activity 4b. Students describing what they have learned	☒Video/audio recording of using the activity in your class ☒Written description of the process ☒Sample of students' work (links, pictures etc.)	In the following links you will find some of the opinions recorded voluntarily by some students. In general, all enjoyed the activity; it was different of what we used to do. Most of them appreciate the

Your Name: Pilar Gonzalez Sanchez	**School:** Institut de Begues	**ILS/laboratory used:** ● ¿Es la radioactividad perjudicial para los humanos? / Radioactivity ● "¿De qué está hecho?" / Density and buoyancy ● "Principio de Arquímedes (I)" / Archimedes Lab Deusto.	**Date:** 29/06/2016
Research Themes/Questions:	**Types of Evidence:** *(Tick the appropriate box when reporting back)*		**Answers (text):**
			advantages that the use of online labs can offer. In the poster linked above you can find links to some of the reports students sent to me. I am pretty satisfied keeping in mind that this was our first time using this kind of activities. Samples of students work (in Catalan/Spanish): http://bit.ly/ILSjuditDensidad http://bit.ly/ILSaliciaArquimedes VIDEOS: https://youtu.be/6AzhmCVTPto https://youtu.be/ajDy2llYklc
29. What was good about the ILS/laboratory you have used and what were the drawbacks?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		They were easy to use for the students. They offer the chance to make some experiences that are not possible to develop in our school lab, sometime because we don't have the resources or maybe because we can't use hazard materials. It was really appreciated that they can organise their time to complete the activity from their house, so it is really useful when you have problems to access a physical lab, or you have time constructions to fit all you want to do.
30. Would you do it again and would you recommend it to your colleagues?	☐Video/audio recording of using the activity in your class ☒Written description of the process ☐Sample of students' work (links, pictures etc.)		Absolutely. We have the intention to use it every school year, as a common resource in our curriculum. I hope that more colleagues engage and try some lab or ILS.

4.2.4.5.1 Conclusions

- In this case of study, already existing labs were used and new ones were created. The main change necessary in order to adapt the ILS's was to translate the information from English to Spanish/Catalan.
- A key advantage of the use of Go-Lab ILS was the possibility for students to finish activities at home. Also, the option of using it in experiments for which the needed resources or materials were not available was extremely useful as it enabled the possibility to develop experiments that otherwise would not be able to be implemented in schools.
- Generally, good feedback was received from the students' side. They appreciated the new possibilities Go-Lab had to offer.
- The feedback received by teachers was really positive and they stated they would definitely use it again.