Next-Lab

Next Generation Stakeholders and Next Level Ecosystem for Collaborative Science Education with Online Labs

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First releases of Labs and Apps

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Executive Summary

The current deliverable describes the first release of labs and apps in the Next-Lab project. The main idea behind the related Task 3.5 is to continuously extend the number of labs available at Golabz (Go-Lab sharing platform, www.golabz.eu) with a target number of 500 labs at the portal at the end of the project. This target number has now already been reached at the end of the first year of the Next-Lab project with 524 labs being presented at Golabz. At the end of the Go-Lab project around 400 labs were available at Golabz, which means that in the first Next-Lab year over 100 labs were added. This makes that currently Golabz is the world's most comprehensive portal of online labs for science education. This deliverable starts with an update on the labs that were added in the first year of Next-Lab. Despite having reached the target number, we will continue to include new labs at the sharing platform.

Another main target of Task 3.5 is to prepare the Go-Lab ecosystem for usage in primary education. Whereas in the Go-Lab project the target age group ranged from 10-18 years old, in Next-Lab this was extended to include younger children, starting at the age of 6. This extension has two main consequences. In the first place, this means that there should be labs available that fit this younger age range. In the current deliverable we analyze the current set of labs available at Golabz for their suitability for primary education and we use the curriculum analysis that is delivered in Next-Lab Deliverable 1.2 to identify gaps where new labs should be found or added. A cooperation has been set up with two larger sets of international lab repositories (PhET and Amrita) to align (and translate) suitable labs from their collection to primary education. In addition to this, new labs for primary education will be developed in Next-Lab. In the current deliverable we will present two examples of these primary education labs developed in Next-Lab (the *Seesaw Lab* and the *Gravity Drop Lab*) and, as an example, we analyze an external lab (the *Photolab*) to identify characteristics of labs that make them suitable for primary education. The *Seesaw Lab* is a special case since this lab is developed in two complementary versions completed with a communication tool (SpeakUp), allowing younger children to discuss the content of the lab and thus stimulating them to exercise 21st century skills (see Next-Lab Deliverable 3.1, Section 2.3.2.2).

A second main adaptation that needs to be done in Next-Lab is making the apps suitable for use in primary education. The current apps were developed with children in the age range of 10-18 in mind; the configuration facilities of the apps already allow to make them less complicated or prepared (e.g., by creating ready made hypotheses in the hypothesis scratchpad) for the younger children in this age range. In Next-Lab we will investigate if the existing apps need further adaptation for the Next-Lab younger age (starting at the age of six years) target group. In the current deliverable the guidelines for these adaptations are formulated on the basis of two first empirical studies on how younger children (and their teachers) view two of the core apps from the Go-Lab set of apps: the hypothesis scratchpad and the experiment design tool. Based on the guidelines these apps will later be adapted.

Next-Lab Task 3.5, also includes work on the backend of the labs and apps in relation to the Go-Lab ecosystem infrastructure. This work is ongoing and will be reported in a later Next-Lab deliverable.

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1. Introduction

One of the unique characteristics of the Go-Lab sharing platform (www.golabz.eu) is that it brings together a large (> 500) set of online laboratories from individuals and organisations worldwide. In this way our sharing platform offers teachers and designers a one-shop opportunity to find suitable online labs. In the Go-Lab project our focus was on students in the age range of 10-18, most of the labs at the sharing platform, therefore, target this age group, but also quite a number of online labs (also) suitable for a younger or an older age group were included. In the Next-Lab project the Go-Lab sharing platform will be specifically extended for the younger age group. The current deliverable starts with an overview of the way and the kind of laboratories that were added to the sharing platform in the first year of Next-Lab and will then continue to make an analysis of the current set of over 500 labs to find out which labs are specifically suited for children in primary education. On the basis of a curriculum analysis performed in Next-Lab Deliverable 1.2, we will identify gaps in the current set of labs to guide the direction for the search or development of new labs. This section of the current deliverable ends with a few examples of online labs together with a set of guidelines for online labs for primary education.

A second distinctive character of the Go-Lab sharing platform is that it offers a large set of apps that teachers can combine with online labs and other multimedia material to create Inquiry Learning Spaces (ILSs). Apps are online tools (Zacharia, et al., 2015) that support students in performing activities that are required for different parts of the inquiry cycle (Pedaste, et al., 2015). In the Go-Lab project these apps were designed with students in the age of 10-18 in mind; now, in Next-Lab, with an extra focus on a younger age group these apps need to be reconsidered for their usability for younger kids. In order to adapt apps and labs for primary school, several factors should be taken into account. These include inquiry level, guidance level, level of difficulty, attractiveness, and language use. An overview of guidelines are presented in this deliverable. These guidelines are partly based on two empirical studies involving two key apps, the hypothesis and scratchpad and the experiment design tool. The outcomes of these studies are presented. The guidelines form the basis for creating new or adapted versions of the apps later in the Next-Lab project.

2. Online labs in the Go-Lab sharing platform

This chapter starts with providing an overview of labs newly added in 2017 to the Go-Lab sharing platform. What follows is a matchmaking analysis of the European curriculum with the set of existing labs. Next is a paragraph with a few examples of online labs for primary education, the Seesaw lab and the Gravity drop lab (both developed in Next-Lab) and the Photolab (already available in Go-Lab). A set of guidelines for labs in primary education follows. This chapter ends with a conclusion on online labs in the Go-Lab sharing platform for primary education.

2.1 Newly added labs to the Go-Lab sharing platform

Since the beginning of the Next-Lab project, 109 labs have been added resulting in a total number of 524 labs on December 1st 2017. This number will increase throughout the Next-Lab project as adding online labs is a constant process.

There were four main approaches to find new labs:

1. Team members are looking for open lab resources or lab authors and invite them to contribute to the Go-Lab project by adding their labs.
2. Team members are monitoring contributors for new labs and add them.
3. Teachers suggest labs which they like to be added to the repository. After receiving such a suggestion, the process is similar to the first approach.
4. Authors publish their labs themselves.

In 2017 in the Next-Lab project, a number of labs were added directly by the lab owners, but most added labs came from larger resources with some Next-Lab team members being in charge of that. The main origin of the added labs is:

- Erik Neumann – 37 (https://www.myphysicslab.com/)
- Concord Consortium – 20 (https://learn.concord.org/)
- Amrita labs – 17 (http://amrita.olabs.edu.in/)
- PhET labs – 10 (https://phet.colorado.edu/en/simulations/category/new)

This allowed the Go-Lab ecosystem to reach a large number of labs in the repository.

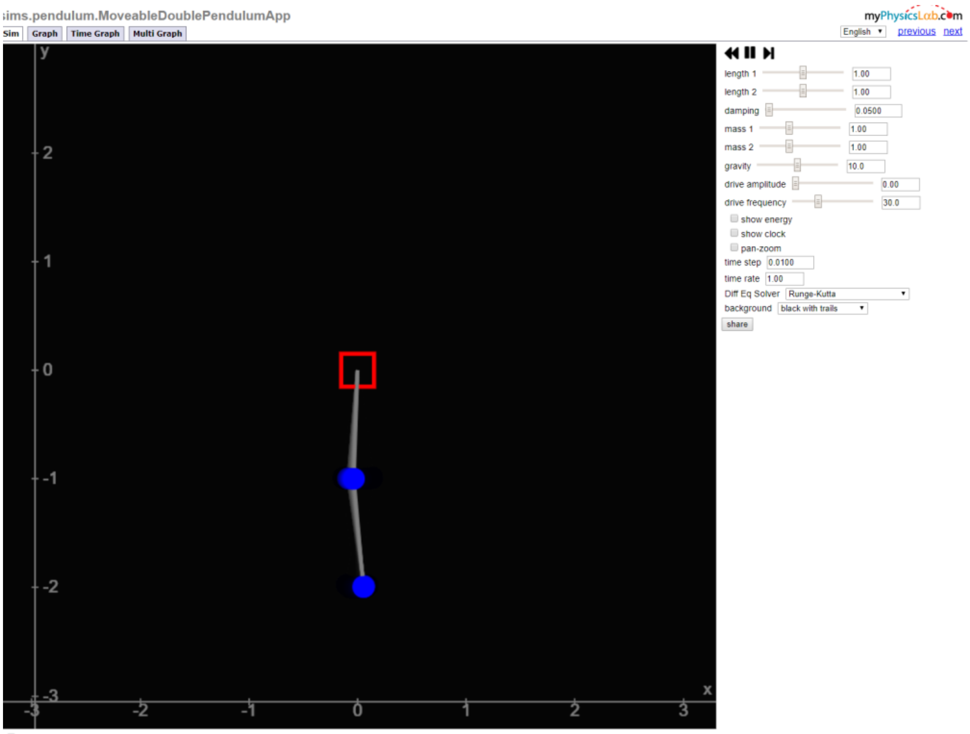
To be added to the Go-Lab sharing platform, labs preferably matches the curriculum of primary or secondary school education in Europe (see Next-Lab Deliverable 1.2) and follow a set of guidelines. The guidelines for adding labs are:

1. Inquiry level - Some exploration should be possible in the lab. Therefore, when there is no option to manipulate variables or explore content and the 'lab' is more an animation, it will not be added.
2. Guidance level - The amount and necessity of guidance that is required for using the lab is taken into account. Sometimes the lab is not that intuitive or the topic requires some hints, both of these issues can be helped with some guidance. On the other hand, too much obligatory guidance limits exploratory freedom of students. Guidance can be offered in the lab itself, but guidance can also be offered in the ILS.

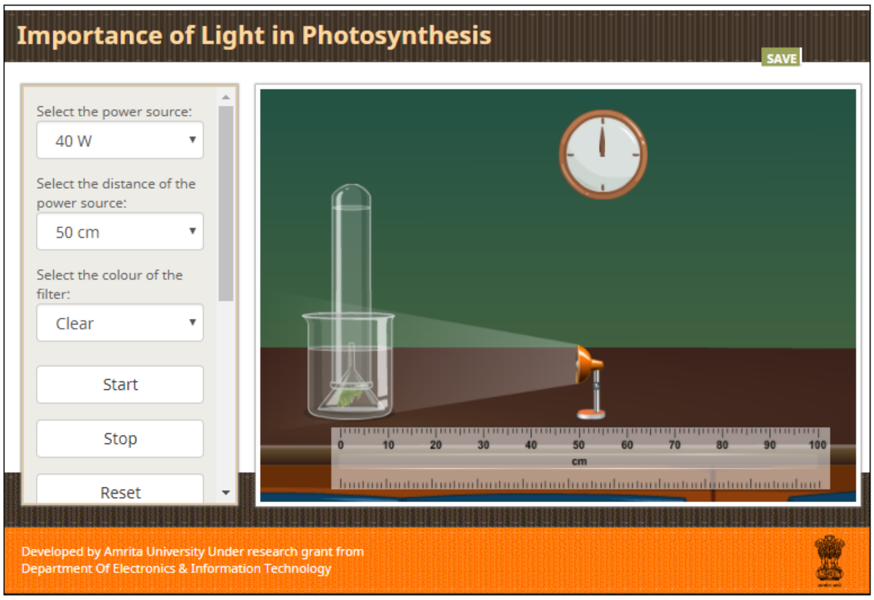
3. Level of difficulty - The level of difficulty guideline states that labs should be comprehensible for school students and relates to the topic of the lab.
4. Attractiveness - The labs should be attractive for the target age group.
5. Language use - The labs should provide textual explanation where needed, i.e., when the graphical display does not suffice.
6. Clear learning objectives - Clear learning goals, either stated in the description or easily deduced for the lab itself, may help teachers when they look for suitable resources. The learning objectives help to match the lab to the curriculum, as well as to the skills and/or attitudes that might be practiced.
7. Technical parameters - The technical parameters refer to the software used by the lab. Currently labs on Java are not added; though the existing ones are still kept in the repository. Labs with Flash are added only when they score high on all other guidelines.

Following these guidelines, that were applied in an intuitive and flexible way, led to adding labs with different features. Here are some examples of different types of labs that were added.

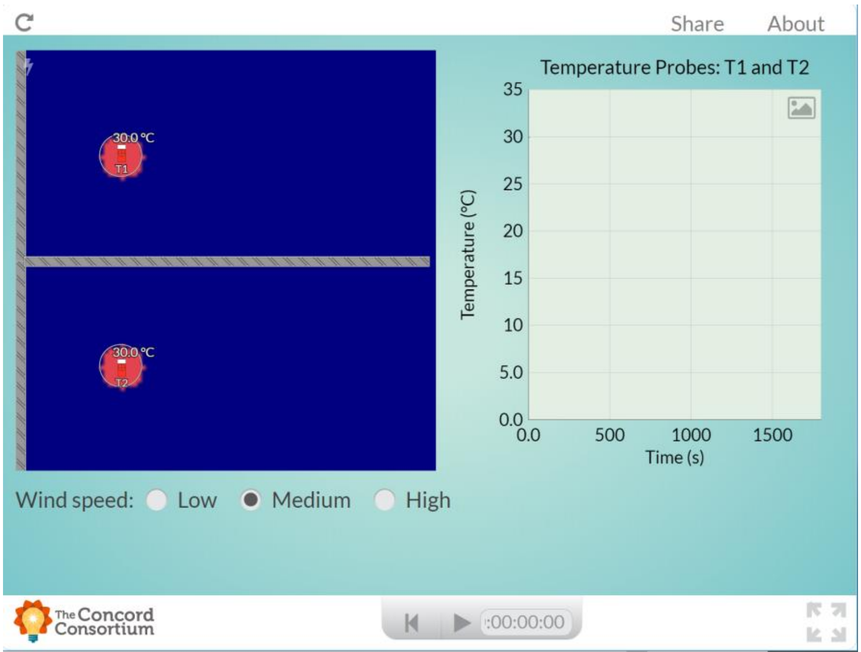
The first type consists of labs which provide a lot of freedom of exploration. Students can change many variables and no specific guidance through the process is given. Nevertheless, the lab focuses on a specific topic and allows a free investigation in this regard. An example is the Moveable Double Pendulum lab (http://www.golabz.eu/lab/moveable-double-pendulum).



The second type presents a more limited way of exploration – the number of variables is smaller, some parameters have only several predefined values, and there is some guidance provided. An example is Importance of Light in Photosynthesis (http://www.golabz.eu/lab/importance-of-light-in-photosynthesis).



The third type enables students to answer a particular research question as only one or two parameters can be manipulated. However, it still facilitates the investigation process. Some examples are Forced convection (http://www.golabz.eu/lab/convection-forced-convection) and Natural Convection (http://www.golabz.eu/lab/convection-natural-convection).



Not all the resources that are published on the Internet as online labs fit the Next-Lab project criteria. The first filter is being free and open. Next-Lab does not include any resources that require paid subscription. Other filters are more content related. Even though many added online labs can also be named as simulations, the main characteristic is that they allow students to manipulate some parameters, observe the results, and make conclusions. Resources that do not give this possibility are not added. Some examples are:

1. Solar system – no possibility of exploration is given, the resource presents a picture and some information:

http://lo.cet.ac.il/player/?document=926ea6df-20a3-4457-9b5f-882263b39d44&language=en&sitekey=mindsonstem

2. Detection of starch in food samples – this is more an animation than a simulation.

http://amrita.olabs.edu.in/?sub=79&brch=15&sim=121&cnt=4

In Next-Lab we are constantly looking for new lab sources, an example of a repository that has been recently found and still needs to be added is http://lsr.hbcse.tifr.res.in/simulations/. It includes six labs about various topics. An important task in the search process is to enrich the collection of labs suitable for primary education (see Section 2.2.2).

2.2 The appropriateness of the online labs for primary school children

Two ways of evaluating the appropriateness of the labs for primary school children were used: 1) use age ranges provided by the authors of the labs, and 2) subsequently judge the appropriateness of the labs based on the formulated guidelines.

2.2.1 Age ranges provided by the authors of the labs

There are age ranges available in the metadata of labs on www.golabz.eu. These were provided by the authors when they uploaded their lab. The age ranges can be used to select labs whose age range matches primary education. An overview of the age ranges and number of labs that match that range is presented in Table 1. This overview includes the labs uploaded to the Go-Lab sharing platform before 1st of December. The total number of labs in Table 1 exceeds the actual total number of labs because a single lab can be suitable for multiple age ranges.

Table 1: Age range and number of labs on the Go-Lab sharing platform

Age range	Number of labs
Before 7	22
7-8	52
9-10	181
11-12	180
13-14	380
15-16	406
Above 16	298

Labs were further analyzed based on the age range. The number of unique labs were counted. First, we selected labs for children below 7 years old. There were 22 labs of which 16 labs were suggested to be suitable for all ages, 2 labs for children up to 10 years, and 4 labs for children up to 12 years of age. For the age range of 7-8 years 52 labs were present, of which 22 included the age range of below 7 years old. This means that 30 unique labs were added to the 22 of the previous age range; so there are 52 unique labs for children aged 8 years old and younger. Out of the 30 unique labs in the age range of 7-8 years, 9 labs were for children aged 7 and older, 8 labs for children aged 7 to 16, 12 labs for age 7 to 12, and 1 lab for age 7 to 10. Third, the age range of 9-10 years was selected. There were 181 labs. We found that all labs with lower age ranges also included the age range of 9-10 years. This means that (181 – 52 =) 129 labs were added to the count of unique labs. Therefore, so far 181 unique labs have been identified. Finally, we selected the age range of 11-12 years. There were 180 labs. Two labs were designed for children aged 11-12 years and older. The rest also mentioned younger age ranges and were already counted. Two labs were added to the count, resulting in 183 unique labs.

To conclude, there are 183 unique labs for primary education available at the Go-Lab sharing platform. This number is based on the age range that was provided by the authors of the labs.

2.2.2 Primary education labs and the European curricula

Given the age ranges specified by the labs and the key topics identified in Next-Lab Deliverable 1.2, available labs on the Go-Lab sharing platform were identified. The key topics were identified by analysing curricula in Europe and by taking the framework for assessment of mathematics and science in the fourth grade (age nine to 10 years old) of the TIMSS 2015 (Mullis & Martin, 2013) into account.

The present analysis of primary education labs resulted in a list of labs that meet two criteria. First, they match the age range of primary education. Second, they match a key topic in European primary school curricula. The age range that was provided by the author of the lab was used. The curriculum analysis resulted in an overview of topics for the two main domains, mathematics and science. The complete overview can be found in Appendix A: Mathematics topics and labs, and Appendix B: Science topics and labs. Below a summary of the findings is presented.

Mathematics

Within mathematics (Appendix A) the topic areas are numbers and calculations (Table A1), measurement (Table A2), geometry (Table A3), and algebra (Table A4).

With regard to numbers and calculations addition, subtraction, multiplication, and division is part of the Unit Rates lab, which presents problems in the context of shopping. In addition, multiplication and division can be practised in the Arithmetic lab. Another topic that is part of a lab is fractions, see the Fraction Matcher lab. Therefore most topics of mathematics are dealt with in labs on the Go-Lab sharing platform. The topics that could be used for new labs are using number with more than two digits, comparing and ordering numbers, rounding up numbers, counting in multiples, the concept of decimals numbers and percentages, the method of long division, dividing and multiplying fractions, and numerical powers.

With reference to measurement, few topics are part of existing labs. In this topic area, three dimensional shapes are relevant, but only two dimensional shapes are part of a lab, namely Area Builder. Another topic is using measurements for money, time, length/height, mass/weight, temperature, capacity, and comparing, ordering, and converting them.

Geometry refers to using and recognizing shapes and angles, calculating perimeters and volumes of shapes, and identifying locations based on cardinal directions, two dimensional grids. Rectangular shapes are dealt with in two dimensional form in the Area Builder lab, but for other shapes and three dimensional forms labs could be added. Angles and circles are part of the Trig Tour lab. Topics that could be used in new labs are triangles and calculating their angles, perimeters, and volumes, and identifying locations.

With respect to algebra, the concept of equality and inequality, how to classify events as certain, possible, and impossible to happen, how to recognise numerical patterns, how to express powers, and the priorities in performing the various calculations are not part of a lab yet. The Expression Exchange lab deals with a third of the topics within this topic areas. Fraction Matcher and Graphing Lines each deal with a topic in this topic area.

An additional topic area is data collection and interpretation, which is somewhat different from the others as it does not deal with specific subjects. Because the Go-Lab sharing platform is about inquiry learning, data collection and interpretation is an important aspect, which is represented in multiple apps. Therefore, labs will not be presented in an overview for this topic area, but three labs, that do not directly deal with data collection and interpretation, but that are related, will be mentioned here. More information about the apps can be found online (http://www.golabz.eu/apps). The apps on the Go-Lab sharing platform deal with all aspects listed in the topic area of data collection and interpretation, except for probabilities, but probabilities is the topic of two labs: Plinko Probability and Statistics Of Rolling Dice. In addition, data representation is part of multiple apps, but there is also a lab that focuses on graphs, which is Graphing Lines.

Science

The other main domain of the curricula is science, see Appendix B for a complete overview of topics and labs. There are five topic areas: materials, processes, and states of matter (Table B1), space and time (Table B2), plants and nature (Table B3), animals and humans (Table B4), and other topics (Table B5).

With regard to materials, processes, and states of matter, there are numerous labs available. Most topics have labs related to them and often the topics are part of multiple labs as well. Topics that could be added to the Go-Lab sharing platform are identify objects and the material they are made from, identify and compare the suitability of everyday objects, energy and the human body, properties of daily materials, compare and group rocks and fossils, properties of air, evaporation and condensation in the water cycle, mixtures and solutions, magnetic forces, how sounds are made, waste management, energy saving techniques, describe electricity related phenomena by using molecules, acids, current energy sources and conscious use, and ardency.

Space and time is small topic area, which is covered by multiple labs of which Seasons And Ecliptic Simulator deals with most topics. Labs could be added about two topics: weather, and volcanoes and earthquakes. It should be noted that there are datasets available on earthquakes, which do allow the students to learn about them, but they are difficult to use and do not allow for experimentation. An example is Earthquake Activity Around Cyprus (http://www.golabz.eu/lab/earthquake-activity-around-cyprus).

With respect to plants and nature, only a few labs are available that deal with it. Photolab and Plant Mineral Nutrition deal with what plants need to grow. Air Pollution concerns the environmental imbalances due to human activities. Labs about the other topics concerning plants and nature can be added. The other topics are classification of plants, identification of their parts, biodiversity, food chains, and cells.

With reference to animals and humans, no labs that are suitable for primary education are currently available on the Go-Lab sharing platform. Other sources can be used as inspiration for two topics. Food chains are already the topic of a simple lab elsewhere (see http://itemsjh.cet.ac.il/units/en/science/unit228/act1-1.aspx). This lab might be added to the Go-Lab sharing platform or one can be made based on this lab. Human health is the topic of various Xplore Health labs on the Go-Lab sharing platform (http://www.golabz.eu/user/149), but they are designed for children in secondary school. These labs can be used as inspiration for how to deal with human health in a lab, but the lab should be made easier in order to be usable for primary school children.

Finally, some topics could not be related to a topic area, the so-called other topics. Labs could be added that have time or orientation as a topic (which were already mentioned in the domain of mathematics). Electrical circuits are also part of the curriculum, but the labs that are available are suited for older children, see the Electrical Circuit Lab for example (http://www.golabz.eu/lab/electrical-circuit-lab). Two labs are suited for primary school children that allows them to explore electrical resistance, called Power Of A Light Bulb and Ohm's Law.

2.2.3 Guidelines for labs for primary education

In order to identify which labs from the the Go-Lab sharing platform are actually suitable for primary education, a set of guidelines was formulated. These guidelines apply to the labs for primary education by taking into account various factors that might affect performance of primary school children in the labs. The guidelines for labs concern inquiry level, guidance level, level of difficulty, attractiveness, and language use. The guidelines are the same as formulated in Section 2.1, but they will be explicated for primary education in the current section. The last two points of the guidelines of Section 2.1, clear learning objectives and technical parameters, will both not be discussed here, because these are general guidelines.

Inquiry level

As the Go-Lab ILSs encourage students to follow an inquiry cycle, the extent of possible exploration given by the lab is important. This guideline was formulated to deal with the exploration that is possible in the lab, because labs differ in this regard. When there are more variables and potential values for of those variables, more exploration by the learner is possible.

In Section 2.1 it has already been stated that exploration should be possible in order for labs to be added to the Go-Lab sharing platform. To make the lab comprehensible for primary school children the amount of exploration should be limited and/or the lab should provide support in what the variables and settings are and how to use them. Primary school children (age 7-11) without training design about half of a trials correctly in experiments with four variables, but with training this percentage is 60 % (Chen & Klahr, 1999). Kindergartners (age 4-6), who receive feedback, design experiments with one variable correctly, and most of them design experiments with three variables correctly (Van der Graaf, Segers, & Verhoeven, 2015). Both studies found an age effect; older children perform better. Both studies used dichotomous variables, which means the number of settings per variable was limited to two.

Primary school guideline: the lab should have a maximum of four variables.

Primary school guideline: the variables in the lab should have a limited amount of settings.

Guidance level

Guidance is a part of the process of going through the inquiry cycle. It has been shown that inquiry learning without any guidance provides little learning gains, but when children are guided in their inquiry process there are significant more learning gains, concerning both inquiry skills and knowledge (Lazonder & Harmsen, 2016). Guidance level of the lab refers to the use of hints and other support that might be needed in order to use the lab to conduct experiments. In addition, the Go-Lab sharing platform provides the user with apps and other multimedia material which can guide children in their inquiry and which may compensate for a lack of guidance in the lab itself.

With respect to primary school education, more guidance is needed than for older children. It has been shown that in general older children are better in inquiry than younger ones throughout primary school and when comparing with secondary school (Zimmerman, 2007).

Primary school guideline: the amount of guidance should be substantial.

Difficulty of the topic

Labs are marked with the recommended age groups, however, they still need to cater for the target group – school children. The other guidelines deal with how understandable and usable a lab can be, and this guideline adds that a lab should have a topic that is comprehensible for the school children. In school specific topics are found to be teachable to the children. One way to find out how suitable specific topics are, is by studying the curriculum, which is done in Next-Lab deliverable D2.1. Even when a topic is part of the curriculum, a topic can be presented in different ways. An example is how to show photosynthesis. Visualizing the growth of the plant is more contextualized and probably easier to understand, than using formula to describe the exchange of chemicals that produce energy.

With respect to primary school education, the topics are more limited and should match primary education curricula. Also, the presentation of the topic should be more contextualized, as this makes it easier to learn (e.g. Boaler, 1993).

Primary school guideline: the lab should be not too difficult for primary school children, as reflected by the topic and how the topic is presented.

Attractiveness

Attractiveness determines the perceived usefulness, ease-of-use, and enjoyment, which affects actual usage (Van der Heijden, 2003). Therefore, labs should be attractive and easy to use for the target age group. Visual attractiveness refers to the visual elements of the lab, such as colours and its overall lay-out. The variables of the lab, for example, can be presented visually, such as a thermometer for manipulating the temperature in the lab. Ease-to-use refers to the degree children believe that using the lab would be free of effort.

Usefulness in an online lab involves as a start, the identification of the variables and how to use them. Based on research on inquiry learning, it is suggested to explicitly introduce variables to the children, so that they can use them in their experiment (Siegler & Chen, 1998; Van der Graaf, et al., 2015). The presentation of variables in the lab can foster the identification and usage of variables. For primary education, the ease-of-use becomes more relevant, as primary school children are less experienced with using digital media. Typing can increase the cognitive load in young children, which can hamper the inquiry process. Therefore, the amount of typing during experimentation in the lab should be limited. Labs would also be easier to use when they support touchscreens. Touchscreens have been effectively used to study four to six year-olds strategy exploration and efficiency (Van der Graaf, Segers, & Verhoeven, 2016).

Primary school guideline: labs should be visually attractive and very easy to use.

Language use

Most labs present some information as text (linguistic), while usually the key elements of the lab are presented graphically (visuospatial). The text that is presented should be comprehensible by using understandable language. An example in the Pressure Equilibrium lab (http://www.golabz.eu/lab/pressure-equilibrium) is the option called ‘Show velocity vectors’. Both ‘velocity’ and ‘vectors’ might be difficult words for young children.

Therefore, the names can be something different, which might be easier to understand, such as ‘direction and speed’. Within primary (or secondary) education, age effects of linguistic knowledge can be present. Therefore, the grade should also be taken into account when determining the suitability of the language used in a lab for the target audience.

Primary school guideline: labs should use language at the level of primary education.

2.3 Three examples of labs

In this section we present three sample labs that fit the curriculum and follow the guidelines.

2.3.1 The Seesaw Lab

The Seesaw Lab (http://www.golabz.eu/lab/seesaw-lab) is an example of a lab that suits the needs and talents of primary school children, see Figure 1. This lab meets the guidelines formulated for primary education. The lab also allows children to cooperate in balancing the beam. For this purpose a special app has also been developed within the Next-Lab project, see the SpeakUp app in Next-Lab Deliverable 3.1.

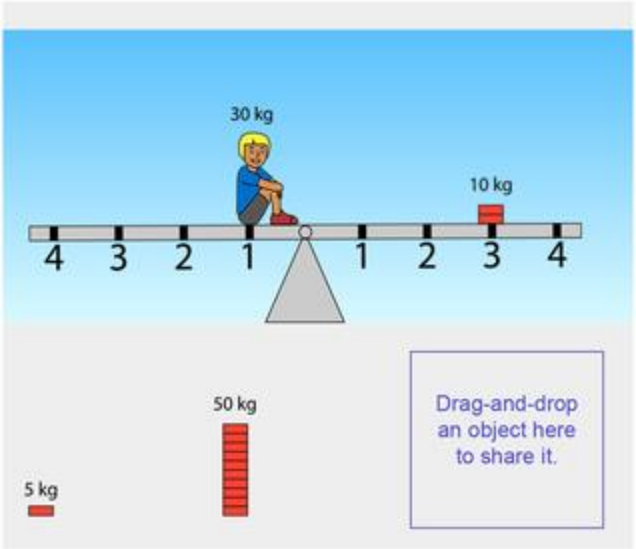


Figure 1: A screenshot of the Seesaw Lab

Inquiry level of the Seesaw Lab

The Seesaw Lab provides two variables to manipulate by the children. One of them is weight (mass is the correct term, but for primary school weight is preferred; Mullis & Martin, 2013) and the other is distance to the fulcrum. The options to manipulate weight are limited to four objects of different weight. The possible distances to the fulcrum are limited to four. This design is appropriate for primary school children, because the number of variables and the number of settings per variable are limited.

Guidance level of the Seesaw Lab

One of the advantages of the seesaw lab is the explication of the possible options where objects can be placed by the numbers that are presented. There are numbers presented below the seesaw, which indicate the different locations objects can be placed. Therefore, the process of designing and conducting experiment is somewhat structured as the options are visible and directly available. This way, children can see what possible settings the variable of distance to the fulcrum has. The same holds for the variable weight. Various objects are directly available and their corresponding weight is presented above them. Although the variables are not explicitly stated, the visual presentation of them allows children to easily deduce what can be manipulated and how. With regard to the results that are produced, they are directly visible. When manipulating one variable at a time, its effect can be determined.

Difficulty of the topic of the Seesaw Lab

The topic of the Seesaw lab is related to the physical phenomenon of forces in balance. It matches the curriculum of primary education, as it is about description of motion and gravitational forces, see Next-Lab Deliverable 1.2. Therefore, the topic is suitable for primary school children.

Attractiveness of the Seesaw Lab

In the Seesaw lab, a simple interface allows users to experiment with the weight of objects and the distance to the fulcrum in order to find out when the seesaw is balanced. The Seesaw Lab has few options, which are all available at the location on which they exert an effect. The objects, for example, can be dragged simply by clicking on them. The locations are highlighted with vertical lines with numbers below them. Finally there is a space in which objects can be shared when using the lab in a collaborative modus. This makes the Seesaw Lab useful, easy to use, and joyful. The lab itself is could be made more visually attractive, but colours are used and the overall lay-out is clean.

Language use in the Seesaw Lab

There is limited language use. Most features are presented visually. There is text to explain that object can be shared. In addition, numbers are presented under the seesaw. The explanation of how to exactly use the lab, if necessary, should thus presented in the inquiry learning space itself. This gives the teacher the freedom to explain the lab in her own words.

2.3.2 The gravity drop lab

The Gravity Drop Lab (http://www.golabz.eu/lab/gravity-drop-lab) is a lab that deals with gravitational forces, see Figure 2. It is a simple lab in that there are few variables with few settings and it is easy to use. Therefore the Gravity Drop Lab is usable for primary school children.

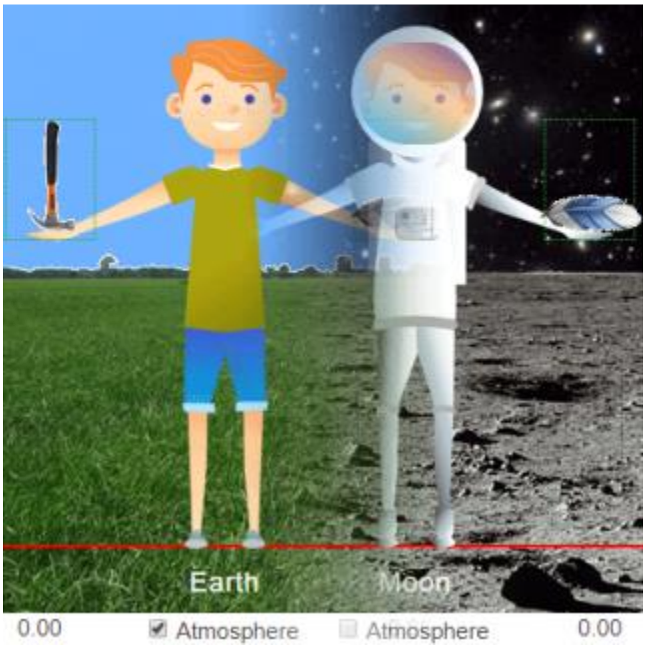


Figure 2: A screenshot of the Gravity Drop Lab

Inquiry level of the Gravity Drop Lab

The variables in the Gravity Drop Lab are location (earth or moon) and weight (mass is the correct term, but for primary school weight is preferred; Mullis & Martin, 2013). Location has two settings namely earth and moon. The settings are visualized. In the lab, there are two screens. The left side shows a boy on earth and the right side shows a boy in spacesuit on the moon. The second variable is weight. This can be set by placing objects in the hands of the boy. There are seven objects with different weights. Although seven can be a bit too much, but due to its ease of use, namely dragging and dropping, and the set-up that allows direct comparison of two objects, no more or less, the variable weight can be investigated easily. This makes the Gravity Drop Lab a good one to explore via inquiry for primary school children.

Guidance level of the Gravity Drop Lab

The Gravity Drop Lab provides guidance in three concrete ways. The first is the predefined set of weights that can be used. The options are directly available, which structures the process of designing experiments. Second, the lab provides the possibility to put two objects in the hands of the boy, which stimulates direct comparison of objects. It can be difficult for primary school children to design an experiment where two settings of a variable are compared, because often they want to generate an effect (e.g. Piekny & Maehler, 2013). Third, the boy already stands on earth (left side of the screen) and on the moon (right side of the screen). Therefore, the lab triggers the investigation of location.

Difficulty of the topic of the Gravity Force Lab

The Gravity Force Lab is about gravity. This is a physics topic, which relates to forces and motion, that is being taught at primary school, see Next-Lab Deliverable 1.2. Therefore the topic to be investigated in the Gravity Force Lab matches what primary school children are capable of. Note that often gravity is being taught as a topic to the older children at primary school, which is from eight to 12 years old.

Attractiveness of the Gravity Force Lab

The Gravity Force Lab is easy to use. As stated, the presentation of the variables, their settings, and how they can be compared makes the lab usable without much effort. In addition, the placement of objects is guided by the highlighted areas around the hands of the boy. With respect to the visual attractiveness, the Gravity Force Lab presents a colourful environment with a young boy, which primary school children might identify with.

Language use in the Gravity Force Lab

Just as the other labs that are mentioned as examples for primary school education, the language use is limited. There are five words, namely earth, moon, atmosphere, pickup, and drop. All of these are easy to comprehend. The only one that might be challenging is atmosphere, but this shows that inquiry learning spaces provide the opportunity to use and practise language, as well as to learn it.

2.3.3 The Photolab

The Photolab (http://www.golabz.eu/lab/photolab) allows children to investigate what factors influence photosynthesis, see Figure 3. While photosynthesis can be complex when you look at the exchange of molecules, the Photolab presents the factors that influence photosynthesis in a simple manner.

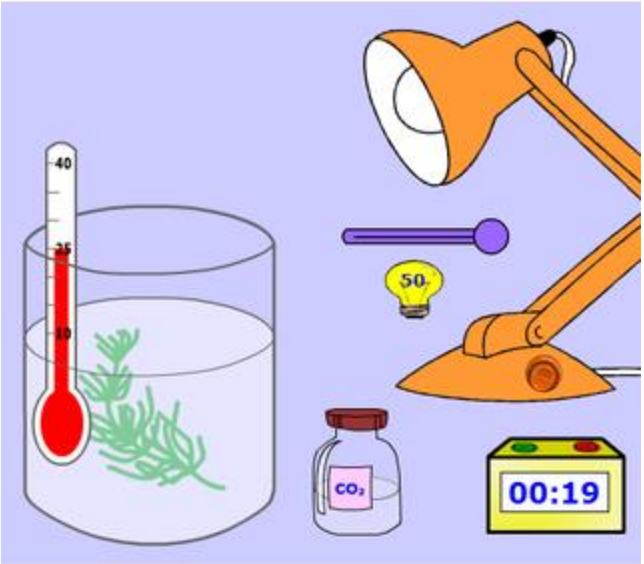


Figure 3: A screenshot of the Photolab

Inquiry level of the Photolab

The Photolab consists of four factors, namely the amount of CO_2, the temperature, the light intensity, and the color of the light. The amount of CO_2 is a dichotomous variable, which means there are two settings. In the Photolab it is a small or a large amount of CO_2. The temperature has three settings. The light intensity has a more settings; there are 10 settings. These range from 10 to 50 with steps of five. The color of light has four settings: orange, green, blue, and white. There are four variables and these have a limited number of settings, which makes the lab suitable for primary school children. The only variable with a large number of settings is light intensity. Therefore, the inquiry level of the Photolab is fitting for primary education, except for the variable light intensity.

Guidance level of the Photolab

All variables of the Photolab have predefined settings. Also most variables have a limited amount of settings. For the variable light intensity there is a slider that can be used. The slider ranges from 0 to 50. The zero is at the left side of the slider and the 50 at the right side and the values in between are arranged accordingly. This makes setting the light intensity doable. The variables are not highlighted, but they are easily identified and it is easy to recognize what each variable stands for. The only variable that is difficult to identify is the color of light, because it is set by using a small button on the lamp. Another way the Photolab might be improved is by a different way of visualizing the effects. Currently, children have to count the number of bubbles that appear within a certain time period, which they have to choose themselves by using the timer. It would be easier when the number of bubbles is automatically counted and presented after a run of an experiment. However, in its present form it provides children the opportunity to practise their measuring skills.

Difficulty of the topic of the Photolab

Plant growth is a central topic in the domain of biology. The Photolab investigates an underlying mechanisms, which is how a plant creates its own energy. It is part of the primary school curriculum, see Next-Lab Deliverable 1.2.

Attractiveness of the Photolab

The colorful interface of the Photolab makes it a visually attractive lab. In addition, the way the variables and their settings can be used is intuitive. As stated, the visualization of the effects could be made more comprehensible, because in its current form the investigation appears to be effortful, which makes the lab less attractive. The way the variables are arranged make them easy to comprehend. The lamp is aimed at the plant. In addition, the temperature can be set by using a thermometer that is situated in the container with the plant. Changing the color of light is directly visible. The amount of CO_2 that is dissolved can be checked by what is left in the jar. This makes the variables easy to comprehend and use, which stimulates the investigation of them.

Language use in the Photolab

The language use is limited. Most features are presented visually. There is text to explain what the variables do when you hover over them. The text is easy to comprehend. One variable that could require some explanation is the amount of CO_2. Primary school children are not familiar with molecules yet. A simple solution would be to call it ‘air’.

2.4 Conclusions on the availability of labs for primary education

In the Next-Lab project new labs are continued to be added to the Go-Lab sharing platform. From the 1st of January to the 1st of December of 2017 more than 100 labs have been added. Of the 524 labs that are currently available, 183 labs were designed for primary education. This was revealed by our analysis of unique labs that correspond to the age range of primary schools in Europe. Our investigation of topics showed that out of the 183 labs in the Go-Lab sharing platform that were indicated as suitable for primary education, 126 covered one or more of the key topics identified in the curriculum analyses (Next-Lab Deliverable D1.2). Most topics are almost completely covered, with the exception of measurement and geometry in the domain of mathematics, as well as some more complex topics of mathematics. Within science, plants and nature, and animals and humans have topics for which no labs yet are available on the Go-Lab sharing platform. The remaining 57 labs that are not part of the present analysis and that are labelled as suitable for primary education do not directly link to one of the topics of the curriculum analysis.

In addition, a set of guidelines was formulated for labs in order to foster inquiry learning of primary school students. These include the inquiry level, guidance level, difficulty of the topic, attractiveness, and language use. These guidelines were used to check the 183 labs that matched the age range of primary school. A representative sample of the 183 primary school labs revealed that most of them follow the guidelines for primary education, but some of them do not. Two examples are Carbon Stabilization Wedges and Curling Stone Momentum. Carbon Stabilization Wedges is a lab with a complex interface and the results are too difficult to interpret. Curling Stone Momentum deals with a topic that is too complex for primary school.

Finally, three labs were discussed that follow the guidelines for primary education and deal with topics that are part of the curriculum for primary education. The labs are examples of how specific topics, in the present examples: forces in balance, gravitation, and plant growth, can be used in a lab for inquiry learning in primary school.

3. The lab repository in the future

Overall, the analysis of labs on the Go-Lab sharing platform showed that there is a large number of labs that relate to the European primary education curriculum and that are suited for use by primary education students. Still, there are some topics from the curriculum that are not covered or for which there are labs that, according to our guidelines, are in need for improvement for primary education. Our search for new online labs for primary education will be focussing on covering these gaps in the Go-Lab sharing platform. Two further alleys will be followed to create a more extensive coverage of the primary education curriculum. First, collaborations have been set up with PhET Interactive Simulations (https://phet.colorado.edu/), and Amrita Online Labs (http://amrita.olabs.edu.in/). As a part of the collaboration, PhET will redesign a number of labs in collaboration with the Next-Lab project so that they will fit the European primary school curriculum. With Amrita, we will select a number of their labs that fit the European curriculum and we will make translations of these labs. For primary education labs (and ILSs) need to be in the local language. If there is a need for a specific curriculum topic that has not been covered and for which no labs can be found and the PhET or Amrita cooperation doesn't lead to a suitable lab, we consider building such a lab within the Next-Lab context.

4. Apps for primary education

4.1 *Evaluation of the hypothesis scratchpad and experiment design tool with primary school children in Cyprus*

4.1.1 Introduction

Referring to the science education curriculum for primary school in Cyprus, the practices of hypothesis formulation and experiment design are acknowledged and emphasized from the 3rd grade until the 6th grade. Therefore, the use of the Hypothesis Scratchpad (HS) and the Experiment Design Tool (EDT) is consistent with the science education curriculum and may contribute to the achievement of the associated learning goals. Specifically, the learning goals outlined in the curriculum are: 1) design and conduct experiment with or without guidance and 2) formulate hypotheses and predictions, test the hypotheses, extract conclusions from the data and share the conclusions.

In order to examine if the aforementioned applications, the HS and the EDT, are appropriate for use in primary education in Cyprus, we conducted interviews with a sample of children who have worked, as a first encounter, in an ILS, in which the HS and the EDT were included in the respective inquiry phases. The ILS was shortened, and its context was well known to the children (plant growth), so that they could focus on the use of the HS and EDT applications. In the next sections of this report we present the methodology followed for data collection and the overall outcomes regarding the use of the HS, the EDT, and the ILS, overall. The outcomes of this report can contribute significantly in adapting and improving the applications for primary education and they can also provide important insights on how inquiry learning spaces can be introduced into the classroom.

4.1.2 Methodology

Participants

Participants were 24 children of a public primary school in Nicosia, from whom 8 were 3rd graders (8-9 years old) and 16 were 4th graders (9-10 years old). The children were familiar with the domain of the ILS used (plant growth). More specifically, the children were familiar with the parts of a plant and they were able to identify variables that may influence the growth of a plant. However, only the 4th graders were familiar with hypothesis formulation, while no child was familiar with experiment design.

The plant growth ILS

The ILS used for the purpose of this evaluation comprised of three inquiry phases, the Orientation, the Conceptualization and the Investigation. However, the phases were renamed into Step 1, Step 2 and Step 3 accordingly, to avoid the use of unknown terminology and to allow children to monitor the sequence of the learning activities. Moreover, the ILS included two main characters; Sofia and Peter (see Figure 4), who narrated the problem and the following steps the children should follow.

Figure 4: Sofia and Peter introduced the children to Step 3 (i.e. the Investigation phase)

In the first phase of the ILS (Step 1), the children were introduced to the idea of the lesson by watching an image presenting the main parts of a plant, which are the leaves, the branch, the flowers, the stem and the roots. Then, the children were asked to complete a short quiz including three multiple choice questions about the role of the leaves, the branch, and the roots. The purpose of the quiz was to allow children to reflect on their previous knowledge and the main variables involved in the next steps of the ILS, i.e., water, sunlight and plant growth. It should be noted that if the children had chosen a wrong answer, then the correct response was given to them as feedback.

In the second phase of the ILS (Step 2), the children were asked to think which variables might impact the growth of a plant and use the HS to formulate one hypothesis. Figure 5 shows the configuration of the HS used for this task (Greek version used). The version of the HS used for this evaluation was the one that it was available in Golabz until that day (the HS has been updated recently). Specifically, the conditionals that were available for use, were *IF*, *THEN*, *there is*, *there is not*, *increases*, *decreases*, *remains the same* and the variables were *sunlight*, *height of the plant* and *amount of water*. Children could also write their own terms using this app.

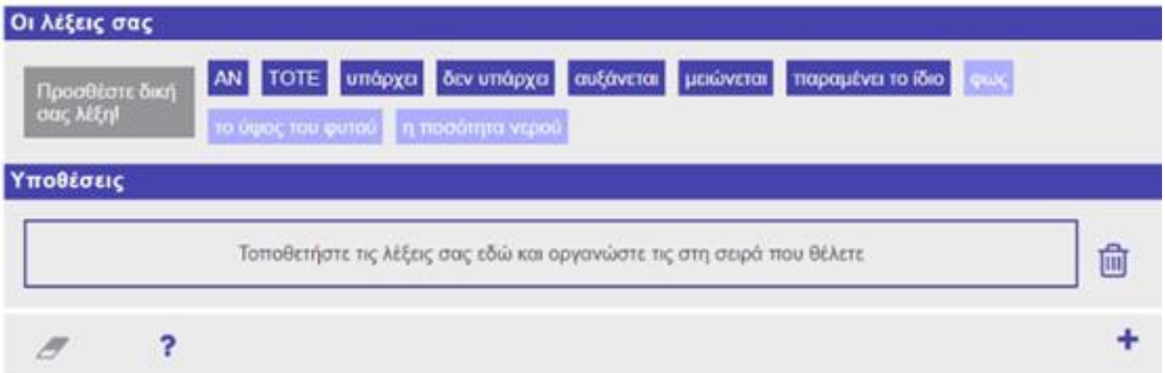


Figure 5: The Hypothesis Scratchpad (Greek version used)

The instructions before the HS prompted the children to read the help by clicking the question mark in the application's interface, which included use guidelines. Moreover, below the HS there was a hidden text that served as a further scaffold for the formulation of a valid hypothesis. If the children wished, they could access the scaffold. The hidden text was referring to an independent context, specifically, the motion of a car, and presented a valid hypothesis for investigating if the size of the wheels impact on how fast the car can move.

In the final phase of the ILS (Step 3), the children were asked to design an experiment to test the hypothesis they had formulated previously. For their experimental design, they used of the EDT, which was configured as presented in Figure 6.

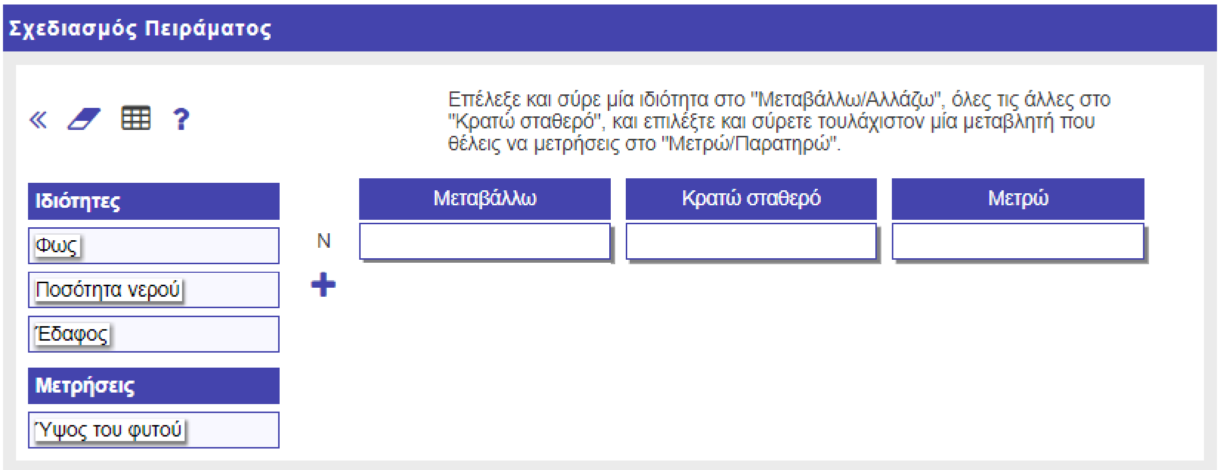


Figure 6: The Experiment Design Tool (Greek version used)

The EDT included three properties: sunlight, amount of water and soil. It also included the height of the plant as a measure. For the specification of the values of each one of the above variables, there were the following predefined values (except for the height of the plant, for which there was a text box available to the children to insert a number):

Sunlight: Sunlight exists / Sunlight does not exist

Amount of water: 50ml, 100ml, 150ml, 200ml

Soil: Sandy, Silty, Clay

Prior to the use of the EDT, the children were prompted to read the step-by-step instructions, which appeared on the interface of the application. In addition, below the EDT, there was a hidden text, explaining the proper manipulation of the variables in a valid experiment. Specifically, the Vary-On-Thing-At-a-Time (VOTAT) strategy was explained. As in Step 2, the children could access the scaffold, if they wished to do so.

Data collection

20 We used three data sources: (1) Think aloud and interview protocol; (2) screen recorded video data; and (3) the learning products that were produced in the ILS by each child, namely, their hypotheses and experimental designs. Screen recording was performed by the River Past Screen Recorder Pro computer software.

Think aloud and interview protocol

First, an explanation of the process to be followed was given to each child personally. Then, the child was informed about the purpose of the activity and it was made clear that the main goal was the evaluation of the applications and the learning environment and not the evaluation of the child's knowledge and abilities. Then instructors used guiding questions to help the child think aloud. Some of these questions were: “Why did you do this?”, “Why cannot you decide?”, “Are you sure about this?”, “Do you want to say more about this?” etc. After the completion of the learning activities of the ILS, the child was asked about his/her overall experience with the ILS and his/her experience with each application. The questions used were: “Did you like it?”, “Was it difficult?”, “Would you like to do it again?”, “How would you compare it with what you do at school?” and “What was the most difficult/the easiest part?” The questions concerning the use of the HS and the EDT, separately formulated for each application, were: “Was the application easy to use?”, “What did you use it for?”, “Was it helpful?”, “Would you use it again?”, “What did you like the most and the least in the application and why?” and “Is there something that you would like to change in this application?”

Screen recorded video data

The activities of the ILS were completed in computers with the screen recorder software installed. Consequently, the video created for each child was a combination of his/her actions and thinking-aloud. The analysis of these data allowed the identification of the children's main difficulties and the kind of support they asked for to overcome them.

Learning products

The third data source was the learning products that children created in the ILS. Specifically, their hypotheses and experimental designs created in each application were automatically saved in the Graasp authoring platform and were retrieved and analyzed for the purpose of this report (for more details on the analysis of learning products, see “Findings”).

Procedures

Four instructors were involved in data collection. Before the visit to the school, the instructors participated in two preparatory meetings, to discuss and think aloud the interview protocol and ensure that they followed the same procedures as interviewers. Data collection was completed within one school visit. During the visit at the school, four separate rooms were available for the interviews with children, which means that four children were interviewed simultaneously by a different instructor in a different room. The duration of each interview lasted 25 – 30 minutes.

The role of each instructor was to monitor the process and provide support to the children whenever they asked for it. During the interview, each child had access to the HS and the EDT in his/her computer. The instructors did not provide any correct answers to the children but only asked them if they were sure about their actions and their learning products.

4.1.3 Findings

The presentation of the main findings is organized in three sections, based on the evaluation of each application and the evaluation of children's overall experience with the ILS. Findings emerged from the analysis of all the data collected, i.e. the videos during the activity, the interviews and the children's learning products. At this point, it should be noted that not all children were involved in all actions that are reported in the analysis or not all of them have answered all questions during the interview. In each case, the number of children been involved, is provided either in brackets or in the text.

Hypothesis Scratchpad

Difficulties encountered when using the HS

When using the HS, the children faced some difficulties (Figure 7). For most of these difficulties, children asked for and received analogous support by the instructor.

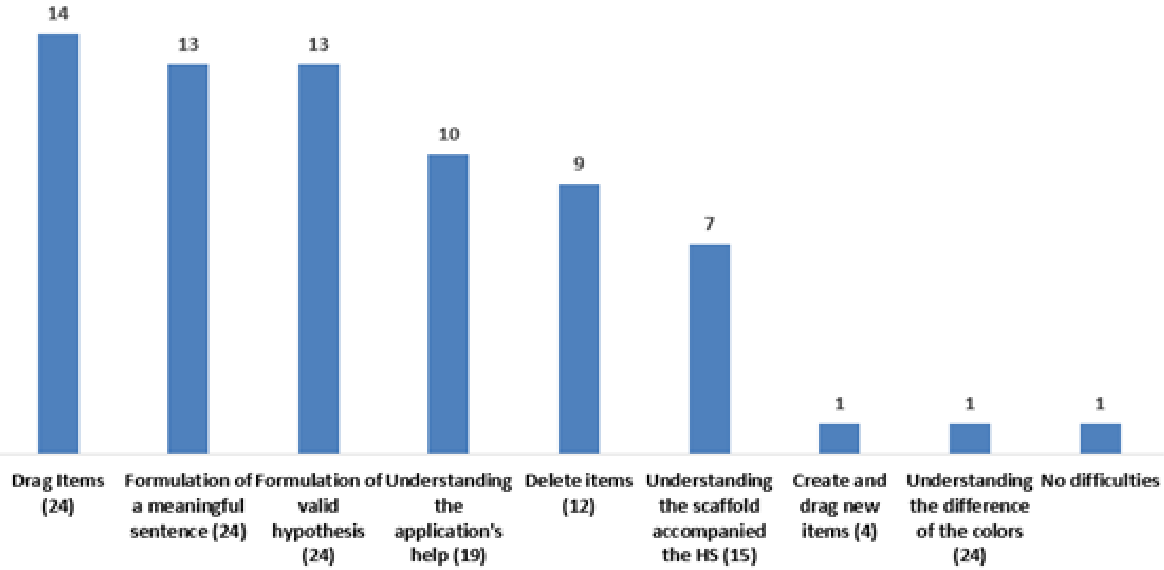


Figure 7: Difficulties encountered by the children when using the Hypothesis Scratchpad (the number of children who have been involved in the relevant action is provided brackets)

More than half of the children (14 out of 24) did not manage to drag and drop successfully their first item, when they started using the application. This might be attributed to the fact that many children did not understand the word “drag” and they were wondering how to begin. Some of them tried to rearrange the terms in the upper part of the application, while others just clicked on the terms and they were expecting to see them move. All the children who faced that difficulty asked the instructor for help and after receiving the analogous support they were able to drag and drop the items easily.

More than half of the children (13 out of 24) had experienced difficulty in formulating a meaningful sentence, because they had thought they should put all the given words in a logical sequence to create one sentence. The following quote illustrates the above claim:

Michalis (3rd grade): Do I have to put all the words?

Instructor: No, you don’t have to use them all. The tool gives you some choices.

A relatively high number of children found it difficult to formulate a valid hypothesis. Specifically, 13 children were unable to use the given terms for producing an “if…then” statement. However, when they were asked by the instructor which variables might impact plant growth and how, they were able to provide some valid responses involving sunlight and water. This might have happened because the children may have not fully realized the HS should be used for the hypothesis formulation.

A considerable number of children, specifically 10, did not know how to start using the HS after having read the help provided by the application. However, not all the children had read that text (5 out of 24).

A technical issue was deletion of items. In that case, 9 children have not been able to delete an item before they received help from the instructor. However, half of the children, did not even try to delete an item when they were formulating their hypothesis.

Another difficulty encountered was that 7 out of 15 children, who had read the scaffold accompanied the HS, did not understand it and they received support from the instructor.

A general observation that should be underlined is that 16 children, namely, two-thirds of the sample needed help from the instructors when going through the verbal content in the second phase of the ILS (Step 2). This referred to the initial instructions, the application's help and the hidden text of the scaffold. The instructors provided assistance to the children in order for them to understand verbal content, anytime the instructors had noticed that the children could not easily read the verbal content provided and anytime the children themselves asked for assistance.

Perceived usage of the HS

The children were asked to indicate whether the application was easy to use, if it was useful, for what purpose they had used it, if they willing to use it again, what did they like the most and the least in the HS and if they wish to change something concerning the application.

As shown in Figure 8 below, 37,5% of the children (9 out of 24) mentioned that the HS was easy to use, 20,8% (5 out of 24) thought it was difficult and another 41,7% (10 out of 24) said that it was neither easy nor difficult. These are some representative child responses:

> *It was difficult to drag the words in the correct sequence (Antreas T., 3rd grade)*
>
> *It was easy because I read the help below and I learnt how to do it (George P., 4th grade)*
>
> *I needed more terms. I knew their meaning, but it was difficult to create a sentence with them (Panagiota, 4th grade)*

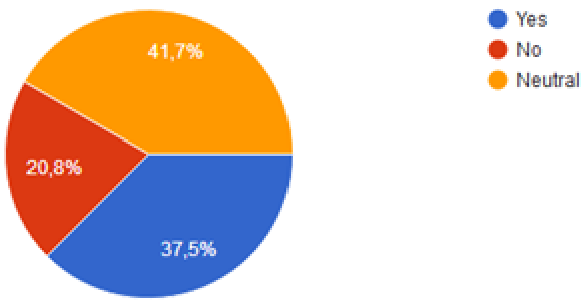


Figure 8: Perceived easiness of use of the HS

It is obvious that the main difficulty for the children has been to grasp the structure of a valid hypothesis, and in this direction, the help and the scaffold in the application seemed helpful for many children.

With regard to perceived usefulness of the HS, 69,6% (16 out of 23) said that it was useful, 4,3% (1 out of 23) said it was not useful and 26,1% (6 out of 23) gave a neutral reply (Figure 9).

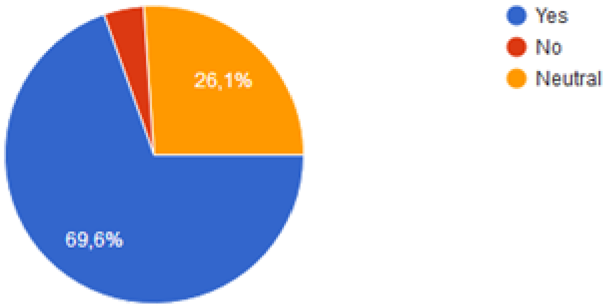


Figure 9: Perceived usefulness of the HS

Many children found the HS useful because it was including the terms needed for the formulation of a hypothesis, and therefore, it was easier for them to create a valid hypothesis. For example, Stavroula (4th grader) said that "*I would not think of these specific terms, so when I saw them in the application I had to think a possible sentence with them, so it was very helpful*".

However, when the children were asked what the purpose of the application was, child responses were scattered across a variety of items, which indicates that the majority of the sample was not able to relate the HS with formulation of hypotheses. Specifically, 8 children (33%) gave no answer to this question, 3 children (13%) clearly stated that they did not know, 6 children (25%) said that the use of the HS was for the conduction of an experiment, 4 children (17%) understood that the purpose of the HS was to help them write their own hypotheses and 3 children (13%) mentioned that they used the HS to help Sofia and Peter. Some of the children's responses are provided below:

> *To organize an experiment (Mirianthi, 3rd grade)*
>
> *To create hypotheses and see if they are correct or wrong (Liza, 4th grade)*
>
> *To give an answer to the question of Sofia and Peter (Irene M., 4th grade)*
>
> *I don't know… to create a sentence? (Chrisanthos, 4th grade)*

Figure 10 shows child responses for willingness to re-use the HS. Most responded positively (77,3%, 17 out of 22 responses).

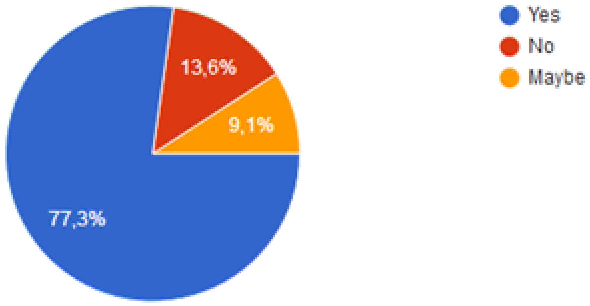


Figure 10: Willingness to re-use the HS

Regarding aspects liked the most and the least, only 13 children responded. Most replies indicated that the children had enjoyed the process of putting the terms together to create one sentence (7 children, 54%). There were some children who mentioned that they liked that the HS included terms for them to use (3 children, 23%) and some children also expressed their satisfaction with the option to create their own terms (3 children, 23%). The following quotes are representative of the above points:

> *I liked that I searched for the proper terms and I put them together (Mirianthi, 3rd grade)*

> *The terms were very helpful, and I liked them (Constantina, 3rd grade)*

> *I liked that I wrote my own terms (Liza, 4th grade)*

Regarding what the children liked the least, there were few answers. Two children claimed that the terms provided were not the proper ones, for example Liza said, “The terms were not good because we don’t use them so often” and one child mentioned that he does not like to read in general, and it was annoying that he had to read the instructions and the help.

Only two children suggested changes for the HS, as it can be seen by their responses below:

> *It is preferable to write here (in the hypothesis textbox), instead of there (in the grey box). It will be easier for me to think what to insert and to make my own choices (Antreas T., 3rd grade)*

> It should have more terms (Antreas D, 4th grade.)

Analysis of learning products

The analysis of children’s learning products (i.e., hypotheses which were formulated in the HS and were saved automatically in Graasp) revealed five categories (Table 2). Given the support from the learning environment and the instructors, the most important outcome here is that the majority of children (13 out of 24, 54%) succeeded in formulating a valid hypothesis, while another 17% (4 out of 24) managed to include the correct independent and dependent variables but failed in the use of conditionals (if, then). All these children were successful in incorporating the correct type of variables in their learning products. However, about one-third of the sample did not manage to either detect the correct variables (1 child, 4%), to include or formulate a testable hypothesis (2 children, 8%) or create a meaningful sentence (4 children, 17%).

Table 2: Categories of hypotheses created by the children

Category	Example	Frequency (%)
Valid hypothesis	IF the amount of water increases THEN the height of the plant increases.	13 (54%)
Correct independent and dependent variables but wrong use of the conditionals (if, then)	IF THEN there is sunlight the height of the plant increases.	4 (17%)
Two independent variables	IF there is sunlight the amount of water increases THEN the height of the plant increases.	1 (4%)

Non-testable hypothesis	The amount of water related to the kind of the plant and the where the plant is.	2 (8%)
Meaningless sentence	THEN the height of the plant remains the same the amount of the water there is not sunlight.	4 (17%)

Experiment Design Tool (EDT)

Difficulties encountered when using the EDT

As in the case of the HS, for most of the difficulties encountered when using the EDT (see Figure 11), the children received guidance from the instructor. In some cases, the children did not ask for support, because they believed that they had completed successfully the task of the experimental design.

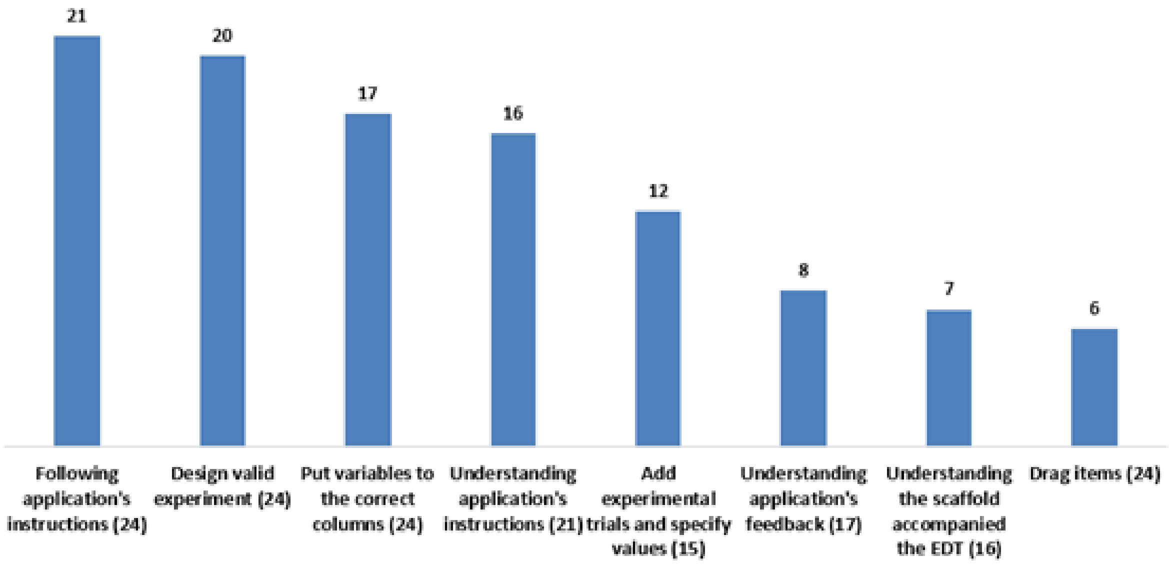


Figure 11: Difficulties encountered by the children when using the Experiment Design Tool (the number of children who have been involved in the relevant action is provided brackets)

A substantial majority of children (16 out of 21, 76%) did not understand the application's instructions. This might be due to the fact that they had several unknown words such as the word Vary. An even greater majority (21 out of 24, 88%) were not able to follow the step-by-step instructions which appeared in the application. That means that they did not realize that the application guided them to complete the process of the experiment design. This might be explained by the fact that the children were less familiar with experimental design as compared to hypothesis formulation. Indeed, there were children who thought that during the experimental design they had to draw the experiment. This might have happened since the term design and draw in Greek language have the same meaning. The following excerpt from the discussion between a child and the instructor explains the above point:

Instructor: Did you understand what you would have to do with this tool?

Antreas D (4th grade). I have to draw the experiment.

Instructor. You mean to draw it?

Antreas D. Yes.

Instructor. You know how to do it? Is that the real purpose of this tool?

Antreas D. No. I don't know what to do.

Another important difficulty was that most of the children (20 out of 24, 83%) did not realize the meaning of a valid experiment and this was obvious since many of them (17 out of 24, 71%) had dragged the properties to the wrong columns (e.g., two properties in the Vary column; the height of the plant in the Keep constant column). When the latter was the case, the pop-up window with a feedback had appeared. Children then referred to the instructor for additional explanation and they seemed unable to handle the feedback on their own. Still, many of them were unable to correct their designs after the feedback they had received either by the application or by the instructor and they seemed to work on a trial-and-error heuristic, mainly operating their actions without any clear rationale or with a rationale that was not aligned to designing an experiment. The following excerpts support the above point:

Excerpt 1

Theodosis (3rd grade). I will put the sunlight to the Keep constant.

Instructor. Why?

Theodosis. Because I was thinking that in the Measure … no because… I will put in the Keep constant.

Instructor. Yes, but why? Is there any specific reason?

Theodosis. I don't know. I just thought I have to do it that way.

Excerpt 2

Instructor. Could you explain your reasoning?

Chrisanthos (4th grade). I believe that the sunlight goes to the Vary column because the light rays move and go on the plant, in the Keep constant column I put the soil because the roots are in the soil and they keep the plant steady and in the Measure column the height of the plant.

One-fourth of the sample (6 out of 24), were not able to drag and drop successfully a property in their first attempt to do so.

A half of the sample (12 children) encountered difficulties when adding experimental trials and/or when specifying values for the variables, mainly because they did not understand the instruction. It should be mentioned that some children, specifically 9, did not even proceed to adding trials and specifying values, either because they were not able to follow the step-by-step instructions or, because they had considered their experimental designs completed.

About one-third of the sample (7 children) did not understand the hidden text that was provided below the EDT as a scaffold for the implementation of the VOTAT strategy. However, only 16 out of 24 children opened the hidden text. Those 7 children asked the instructor to explain the text, while the other 9 children were able to understand the text, mainly because it contained similar information as the first part of the step-by-step instructions also included in the application's interface.

Perceived usage of the EDT

The sample was equally split among responses in the case of perceived easiness of use of the EDT (Figure 12). Regarding their comments, 7 children mentioned that they could not decide which column they were supposed to assign the properties to, and another two children stated that the instructions in the application were complex. These are two representative responses:

> *I was confused with the height of the plant, because I put it in the Keep Constant column (Anna, 4th grade)*
>
> *The instruction was difficult; it was not clear (Antreas D., 4th grade)*

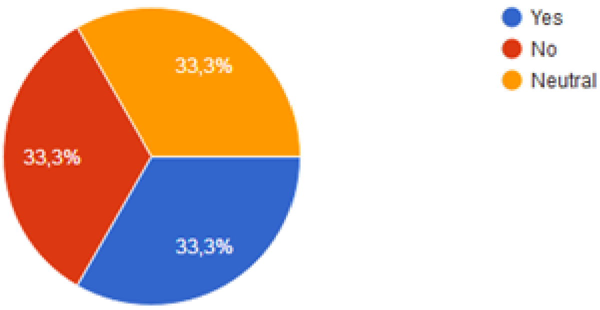


Figure 12: Perceived easiness of use of the EDT

With regard to perceived usefulness of the EDT, children's responses are depicted in Figure 13. Most of children (14 out of 23, 61%) considered that the application was useful, while 3 children (13%) supported that it was not. Some children (6 out of 23, 26%) were not able to decide if the EDT was useful or not. This might be attributed to the fact that they did not understand why they had used the EDT. Specifically, 4 children stated that they did not know what the purpose of the application was. Moreover, 7 children had related the use of the application with either the context of the plant growth or with a matching exercise. For example, Bogdan (4th grade) replied that the purpose of the application was "*for the plant and the water*" while Mirianthi (3rd grade) thought that the purpose was "*to put the words where they fit better*".

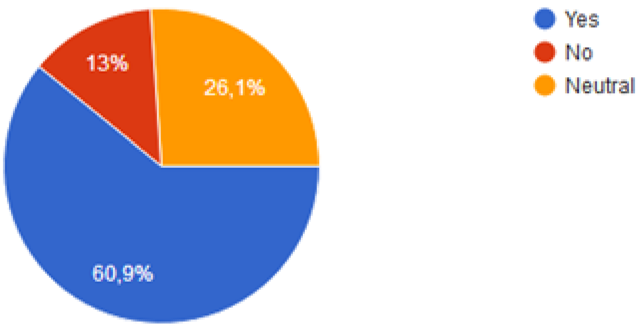


Figure 13: Perceived usefulness of the EDT

In terms of willingness to re-use the EDT, 15 out of 21 children replied positively. When asked to mention what they liked most and least about the EDT, the majority did not give a specific answer. Some children said they had liked everything in the application and some other replied that they could not decide. Among those who replied, the process followed in the application was considered as interesting (mentioned by 5 children) and the predefined values for variable specification were considered as useful (mentioned by 2 children).

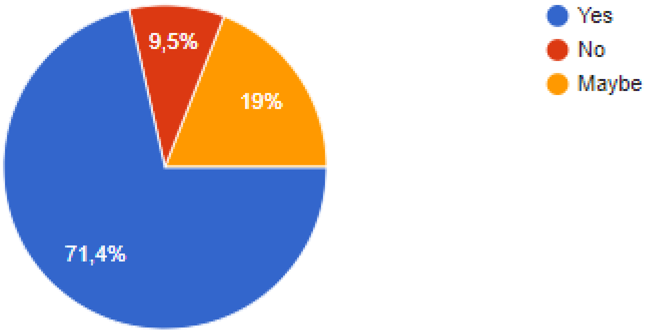


Figure 14: Willingness to re-use the EDT

It is noteworthy that no child mentioned any negative aspect of the EDT and only three children had a suggestion for improving the EDT. Specifically, one child requested more properties available to have more options during the experimental design and two children complained about the instructions and requested that they had to be more precise.

Analysis of learning products

From the analysis of the learning products (i.e., children's experimental designs), which were retrieved from their ILSs, seven categories emerged (Table 3). As in the case of the children's hypotheses, the analysis was performed using the final learning products of the children, which means that most them were modified after the children had received support either from the learning environment or the instructor.

Table 3: Categories of experimental designs created by the children

Categories of experimental designs	Frequency (%)
Experimental design corresponds to the hypothesis, VOTAT, at least 3 experimental trials with values	6 (25%)
Experimental design corresponds to the hypothesis, VOTAT, only one experimental trial with values	5 (21%)
Experimental design corresponds to the hypothesis, no VOTAT, no experimental trials	1 (4%)
Experimental design does not correspond to the hypothesis, VOTAT, at least 2 experimental trials with values	2 (8%)
Experimental design does not correspond to the hypothesis, VOTAT, no experimental trials	2 (8%)
Experimental design does not correspond to the hypothesis, no VOTAT, at least one experimental trial with values	2 (8%)
Experimental design does not correspond to the hypothesis, no VOTAT, no experimental trials	6 (25%)

Half of the sample was able to produce an experimental design that corresponded to their hypotheses. Among these children, six (25%) used the VOTAT heuristic and inserted at least 3 experimental trials with values, 5 children (21%) used the VOTAT heuristic but inserted one experimental trial with values only, while 1 child (4%) did not use the VOTAT heuristic and did not insert any experimental trial.

Use of the ILS

The last section outlines the general outcomes regarding the use of the ILS, overall. Figure 15 displays the percentages of children who encountered difficulties in reading (how difficult it was to read a text), reading comprehension (how difficult it was to understand a text) and language (language provided in the ILS and applications vs language confidence of children).

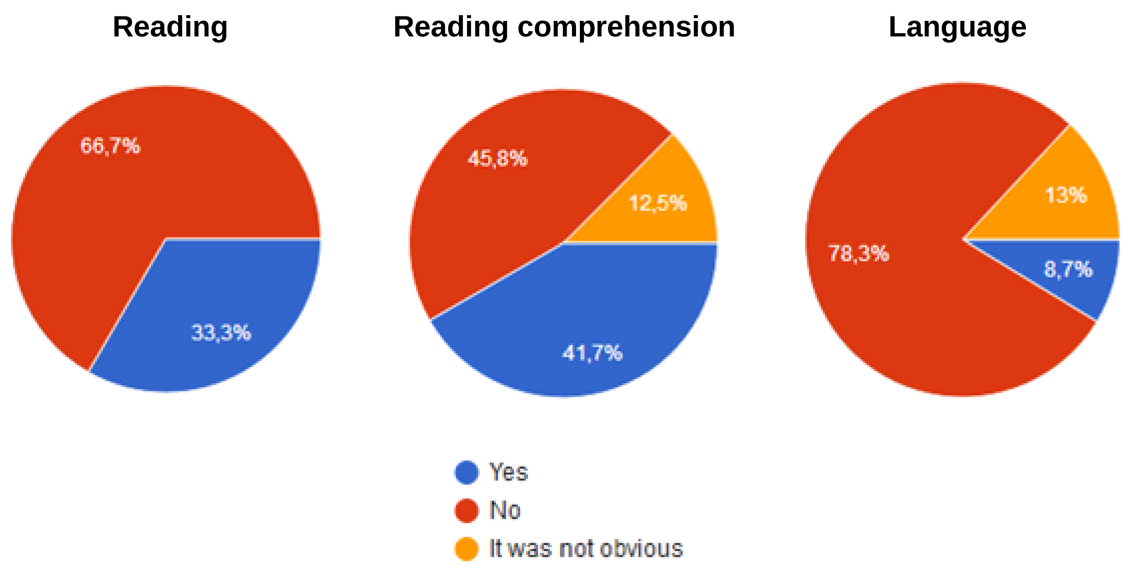


Figure 15: General difficulties when using the ILS

One-third of the children encountered difficulty in reading, 10 children (15%) had problems in understanding the texts, while 2 (9%) had lower language confidence than reflected in the ILS and applications. The most crucial issue is that problems in reading comprehension (41,7%) were more frequent than problems with speaking Greek (8,7%). Overall, reading comprehension seems to have been the main obstacle for the completion of learning activities, since most children, after reading a text, did not know exactly how to proceed in the ILS and they were asking the instructors for support. Furthermore, many children needed help to understand the meaning of some terms that appeared in the texts, such as “variable”, “drag”, “application”, “formulate”, etc.

Interviews revealed that all children acknowledged that the ILS was interesting, and that they liked working with it. In terms of perceived easiness of the entire ILS, the sample was divided among those who replied that the ILS was easy to complete (9 out of 19 responses, 47%) and those who indicated that the ILS was neither easy nor difficult to complete (9 out of 19 responses, 47%), while only one child (5%) responded that the ILS was difficult to complete. The main difficulty when dealing with the ILS as a whole, as most of the children mentioned, was that they were not sure how to work with the applications when they started using them. After they had received support from the instructor, however, the procedures were considered to be easier. Finally, 85% of the children (17 out of 20 responses) expressed their willingness to use an ILS again, while 15% (3 out of 20 responses) preferred not to use a similar learning environment in the future because the activities were quite demanding.

4.1.4 Conclusions

As it can be concluded based on the findings presented above, the main difficulty encountered when 3rd and 4th graders used the HS and EDT for their first time was familiarity with concepts related to formulating hypotheses and designing experiments, which may refer to inquiry skills, overall, rather than the use of the applications per se. This may also explain why some children could not complete learning activities, especially, experimental designs for testing their hypotheses, even after they had received support from either the learning environment or the instructor.

Most children found the EDT more complex than the HS. They could not easily understand the rationale in implementing the VOTAT heuristic in their experimental designs and they did not realize the importance of inserting multiple experimental trials. Another main issue has been the language used in the ILS. If the children encountered many unknown terms, then they could not have been able to complete the learning tasks related to the applications appropriately, i.e., formulating hypotheses and designing experiments. For example, many children did not understand the meaning of the terms, formulation, vary and variables.

Regarding technical aspects of applications, the children encountered problems when they started using the HS or the EDT but they could easily move on after they had received support in the usage of applications from the learning environment or the instructor. Those who stated that the applications remained difficult to use explained that this was due to their inability to understand the instructions. Overall, it seems that some difficulties due the first use of application may not appear again in next uses, after children have been familiarized with them.

Suggestions for improving the HS for use by primary school children may involve more examples for the terms identified as difficult to follow by the children and some adjustments in the operationalization of basic actions, such as deleting an item. Since the help provided by the applications is configurable, this suggestion might be especially important for primary school teachers who wish to integrate the HS in an ILSs.

Concerning the EDT, a main suggestion is to change the way the step-by-step instructions will be introduced to the children. For instance, these may be provided by a series of pop-up messages to allow children follow the sequence of the steps needed and their rationale, as well.

Despite the difficulties highlighted in this evaluation, regarding the use of the HS and the EDT, most children had enjoyed the learning activities in the ILS and they expressed their willingness to undertake similar learning activities in the future. At the same time, many children had elaborated on the difficulties they had faced while using the applications. This inconsistency might be explained by the fact that during the interview the children might have responded positively in order to please the researcher. The HS seems easier to use in primary education, while the EDT is considered more complex by younger children, not because the children have difficulties in using the application itself but probably because it is too soon for them to engage in configuring an experimental design. We assume that this difference between the two applications will remain even after children become more experienced with the EDT. In any case, it is crucial to ensure that children have the skill of designing an experiment before introducing the EDT into a classroom.

4.2 Evaluation of the hypothesis scratchpad and experiment design tool with primary school children in Estonia

The ILS described in Section 4.1 for evaluating the hypothesis scratchpad (HS) and experiment design tool (EDT) with primary school children was translated into Estonian and tested with children in Estonia (a link to the Estonian ILS can be found here). This permitted us to compare the results of implementing the same ILS with primary school children who are learning in two different educational systems. Consequently, similar findings from these two studies provide support to suggest that issues children may have with the HS or EDT are generalizable to a larger primary school population in Europe.

In Estonia, the study was conducted by three researchers who went to a local school and implemented the ILS in a teacher's regular classroom during regular school hours. The study lasted 45 minutes and 22 children (7 girls, 15 boys) aged 9 to 10 years participated. Two researchers worked with two individual children (a boy and a girl selected by the teacher) in a think-aloud procedure to document what each child thought when working through the ILS. The third researcher worked with the remaining children to help answer questions about the ILS and to document the experience through observations.

Primary school children in Estonia typically sit next to each other in pairs with each pair sharing a common desk. This is meant to facilitate interaction in pairs or small groups for collaborative work. However, for this study we asked the children to perform their work independently. Each child was provided with an internet-enabled tablet computer to work individually, aside from two pairs of children who had to share tablets and therefore worked collaboratively to complete the ILS. The tablets were part of the school's ICT infrastructure and the internet was available through the school's Wi-Fi network. The children were informed that the study would last the entire length of a class period (i.e., 45 minutes). After a short introduction the children were allowed to login to the ILS using a given procedure and began reading and completing the assignment. The two children who participated in the think-aloud protocol were provided with additional instructions to verbalize their thoughts while interacting with the ILS, and they were made aware of the fact that the researchers would intermittently ask them questions and prompt them for additional clarifications.

The first inquiry phase of the ILS introduced children to the scenario about plant growth and concluded with a quiz about the parts of plants and their functions. The quiz consisted of three multiple-choice questions. Each question had four possible answers of which only one was correct. Twenty quiz responses by each child/pair of children were saved by the ILS. Analysis of the quiz responses showed that only two children (10%) answered all three questions correctly, three children (15%) answered at least two questions correctly, eight children (40%) answered at least one question correctly and seven children (35%) did not answer any question correctly. The quiz responses also seemed to suggest that the children did not read all of the possible answers before answering. From the think-aloud protocol it was observed that a child's finger accidentally selected a response in the quiz due to scrolling on the tablet computer. Because the quiz tool was set to provide instant feedback after the children answered the question, this accidental selection caused the child to make an incorrect response. Nevertheless, the think-aloud protocol revealed that the children enjoyed answering the quiz questions and benefited from the feedback the Quiz tool provides if an answer is incorrect.

The second inquiry phase of the ILS required children to construct a hypothesis using the hypothesis scratchpad app. In the ILS an explanation of what a hypothesis is was given and children were instructed to think about what plants need to grow. Then they were asked to construct a hypothesis using the HS. The HS included the prescribed terms: *IF*, *THEN*, *there is*, *there is not*, *increases*, *decreases*, *remains the same*, *sunlight*, *plant of the height* and *amount of water*. Children could also write their own terms using this app. At the end of the second inquiry phase a hint was given on how to construct a good hypothesis. The hint stated that a good hypothesis can be formulated in the form of an if ...then statement, in which two variables are compared. The hint also gave an example: “If the size of a car’s wheels increases, then the car can move faster.” The hypotheses generated by each child/pair of children were saved by the ILS. Analysis of the hypotheses showed that 13 children (65%) used the correct *if...then* sentence construction to form their hypothesis, whereas 7 (35%) did not. In fact, 18 of 20 hypotheses began with the word *if*, but 5 did not include the word *then* later in the hypothesis. During implementation of the ILS, it was often asked by the children what they had to do with the HS, suggesting that the instructions were not immediately understandable to them. In addition, even after some of them realized that they have to drag-and-drop words to construct a hypothesis, they still had difficulties joining words together into an intelligible sentence. At least one child thought they had to use all of the words provided to form a hypothesis. From the think-aloud protocol it was observed that because the hint for constructing a good hypothesis was placed after the HS, the children using tablets did not see it and struggled to understand what to do with the HS. Furthermore, there occurred a display error with some Estonian words when displaying the special characters õäöü after a refresh of the web browser. Finally, the children were in general unfamiliar with the terms hypothesis, independent variable and dependent variable. This was their first exposure to such terms.

The third and final inquiry phase of the ILS required children to use the experiment design tool to plan experiments. Analysis of data saved by the EDT showed that 12 of 20 responses (60%) had entered at least one trial, but only 7 of 20 (35%) had entered three or more trials. Questions by the children during the intervention suggested that using the EDT was quite challenging. Some children may have rushed through this part of the ILS without really understanding what they were doing. Moreover, when children used the EDT it appeared that they did not rely on their previously postulated hypothesis to prepare an experimental plan. From the think-aloud protocol it was corroborated that the child was not relying on his or her previously postulated hypothesis to construct experimental plans. Also, the child expressed confusion over how the EDT should work.

An informal classroom poll at the end of lesson asked the children about their experience with this ILS. When asked whether they liked it: 0 said they did not like it, 5 (23%) said they liked it a little and 17 (77%) said they liked it. When asked whether they would like to work on a similar activity again in the future: 19 (86%) said yes and 3 (14%) said no. Thus, it appears that once children received support to overcome various initial difficulties they encountered in the ILS, they could easily continue completing the activity and enjoyed the experience. The teacher also remarked that she liked the activity, although she believed that children with better reading ability would probably benefit the most from it.

From this study several suggestions for adapting the HS and EDT for primary school children can be made. First of all, it is important to keep in mind that children are encountering this unfamiliar learning activity for the first time and need time to get familiar with it. Therefore, in general it is recommended that the teacher demonstrates and guides children with parts of an ILS that may be more challenging. For example, before children use the HS to formulate a hypothesis on their own, a teacher could demonstrate and model how to use the HS using a worked example. The teacher could present a short problem where a hypothesis has to be constructed and think aloud while constructing her hypothesis. This would allow children to focus on the specific steps of constructing a hypothesis with the HT. Second, it appears that the EDT in its present form may be too cognitively complex for primarily school learners. The EDT presents the entire range of experimental planning (identifying independent and dependent variables, setting values of variables, recording the outcomes of experimental trials) and may overwhelm primary school learners. In this case it is suggested to explore if only parts of the experimental design process can be supported by the EDT at one time, if written text instructions could be replaced with more intuitive picture-based guidance and if an EDT that is initially scaffolded (i.e., some prescribed experimental trials are already present) could benefit primary school learners. Overall, the ILS experience with primary school children may also benefit from the teacher checking for learner understanding at several different points to ensure that children are learning the new material. This could involve asking questions, asking children to summarize their work up to that point or initiating classroom discussions.

4.3 Suggestions for adaptation of the hypothesis and question scratchpads and experiment design tool

Both studies show that there is a substantial number of primary education students who can work with the apps also on first encounter. and that the apps (and the ILS) were appreciated by many children. Both studies, however, also point out that primary school children, in their first encounter with apps like HS and the EDT do need some form of guidance and that the apps, the HS and EDT, do not fully fulfill this need. Improvements have been proposed based on the results and a summary is presented here.

With reference to the HS, there appeared to be a general difficulty with understanding what to use the app for. An example is the question whether all terms should be used. This might be related to difficulties in understanding what hypotheses are and what they are for with respect to inquiry. Therefore, the word ‘hypothesis’ might be changed to something that is easier to understand for primary school children. Option is to call it ‘expectation’ or ‘idea’, because that is what the HS often is used for.

Another difficulty was the usage of terms. A simple interface-related problem was the dragging-and-dropping and removing of terms. Especially the removal of terms appeared to be difficult, because they had to be dragged to a specific area for removal. A suggestion would be to allow dragging terms outside of the hypothesis area in order to remove them.

In addition, there is one term that allows users to type something themselves. This can be done in the location of the HS where the terms are presented, but it appeared to be more intuitive to allow typing at the location where the hypothesis is created. This would improve the HS.

Not all children could use the terms to create a meaningful sentence or intelligible hypothesis. This indicates that children should have some school-related vocabulary with words such as ‘comparison’, ‘if’, and ‘then’, and some domain-related vocabulary, such as ‘plant growth’, before they can properly generate hypotheses. A suggestion would be to explain such concepts beforehand and another suggestion is to use them in a worked example, which was also highlighted by the results of the studies. The HS can incorporate worked examples in the first place by providing specific terms to choose from and in the second place teachers can also put some terms in place for the children.

Other suggestions to make the HS better fit for primary education is to make it more graphical or to use spoken text instead of written elements. Primary education students would also possibly profit from getting online feedback on the hypotheses that they entered.

With regard to the EDT, a similar general difficulty with understanding what the app is used for was found. However, this might be less related to the language used, but more to the use of experimental strategies, such as the VOTAT strategy. Such strategies often require multiple trials in order to generate informative results. This is supported by the notion that children often did not create more than one trial. A suggestion is to explicate the need for comparison on the EDT, for example by providing two lines in advance. There could be text, such as ‘I want to set up the experiment like this: trial one’ and then for the second line ‘and compare it with this set-up: trial two’.

Usage of the EDT was also troubled by the language that was used and that was needed to comprehend what should be done. Examples of difficult words are ‘vary’, ‘compare’, and ‘valid’. In the EDT there are multiple columns. One of them is about variables that children want to vary, one of them is about variables that children want to keep constant, and the final one is about variables that children want to measure. The first two columns appeared to be difficult to comprehend; children did not know what to do without instruction. Therefore, the language in the EDT can be changed. In line with the addition of text to explicate comparison, the word ‘vary’ could be replaced with ‘change’, whereas ‘constant’ can be replaced by ‘same’.

Even when it is clear what the children should do in the EDT and how it works, designing experiments appeared to be a complex process. A solution that was proposed is to use a step-by-step instruction. There could be a pop-up asking for which variable should be investigated, after which it is placed in the table of the EDT. Then a new pop-up can ask what the children want to measure and finally what they want to do with the other variables.

The EDT has, just as the HS, the possibility to predefine which settings can be chosen. In the case of the EDT, this means that the variables were specified and were presented to the children in the EDT. The limited set of variables, which the children could use, was something they thought was useful.

Finally, the evaluation revealed that the children thought both apps were interesting and useful. This could be due to a tendency to comply with the research, but they might actually like it, as the teachers were also positive. Thus, they provide guidance in the inquiry process, but they might be improved.

Based on the evaluations of the HS and EDT some general guidelines can be formulated that also extend to other apps. First, it is clear that the language used so far and that was suited for an older age range doesn't necessarily fit primary school children.. Second, other words that are not directly related to inquiry should be explained beforehand, such as 'comparison' and 'application'. Third, a step-by-step procedure can help in complex processes, for example in designing an experiment. Fourth, the aim of the app should be explicitly introduced, so children know what they can and should use the app for. Fifth, what inquiry is should also be explained to some extent in addition to how the apps can help in inquiry learning. Finally, visual presentations can help in clarifying the inquiry process, such as pictures of the variables and their settings.

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6. Appendix A: Mathematics topics and labs

Table A1: Labs that correspond to the mathematics topic area: numbers and calculations

Age	Numbers and calculations	Availability of labs on the Go-Lab sharing platform
5 - 6	**Pupils learn:** • to recognize, read, write, compare, order two digits natural numbers; • to read, write and interpret mathematical statements involving addition (+), subtraction (–) and equals (=) signs; • addition and subtraction: how to solve one-step problems that involve addition and subtraction; • to understand simple fractions.	**Lab availability:** • yes, Unit Rates • yes, Arithmetic and Expression Exchange • yes, Unit Rates • yes, Fraction Matcher
6 - 7	**Pupils learn:** • to recognize, read, write, compare, order natural numbers of up to 3 digits • compare and order numbers using <, > and = signs; • the multiplication tables (2,3,4,5,10), including recognising odd and even numbers; • to solve problems involving simple multiplication and division; • to recognise and use the inverse relationship between addition and subtraction; • to add and subtract numbers using concrete objects, pictorial representations, and mentally	**Lab availability:** • no labs • no labs • yes, Arithmetic, but no labs for odd and even numbers • yes, Arithmetic • yes, Unit Rates • yes, Unit Rates
7 - 8	**Pupils learn:** • to recognize, read, write, compare, order four digit numbers; • to round up numbers to the nearest 10, 100, 1000 • how add and subtract three digit numbers • how to multiply one digit numbers with 10, 100, 1000 • how to solve problems by combining addition and multiplication, and the concept of division • to count from 0 in multiples of 4, 8, 50 and 100; • find 10 or 100 more or less than a given number • recognise the place value of each digit in a three-digit number (hundreds, tens, ones) • compare and order numbers up to 1000 • Identify, represent and estimate numbers using different representations.	**Lab availability:** • no labs • no labs • no labs • no labs • yes, Unit Rates • no labs • no labs • no labs • no labs • yes, Fraction Matcher
8 - 9	**Pupils learn:** • to recognize, read, write, compare, order, round up, add and subtract numbers up to 1 000 000 • to multiply and divide long numbers; • the concept of decimal numbers and how to convert fractions to decimal numbers; • how to compare numbers with the same number of decimal places up to two decimal places; • how to present numbers as fractions, how to convert fractions in decimal numbers and how to compare fractions • how to add and subtract fractions and solve simple measure and money problems involving fractions and decimals to two decimal places	**Lab availability:** • no labs • no labs • no labs • yes, Unit Rates • yes, Fraction Matcher for comparing fractions only • yes, Unit Rates

Age	Numbers and calculations	Availability of labs on the Go-Lab sharing platform
9 - 10	**Pupils learn:** • to recognize, read, write, compare, order numbers up to 1 000 000 000; • about negative numbers; • how to simplify fractions; • how to compare, add and subtract proper and improper fractions; • how to convert fractions to decimal numbers; • how to multiply a natural number with a fraction; • the methodology of long division; • how to recognise the percent symbol (%) and understand that per cent relates to 'number of parts per hundred'	**Lab availability:** • no labs • no labs • no labs • yes, Fraction Matcher • no labs • no labs • no labs • no labs
10 - 11	**Pupils learn:** • to recognize, read, write, compare, order numbers up to 9 digits; • the concept of negative numbers; • to work and solve problems with percentages; • deepen their understanding on long division; • how to divide and multiply fractions; • the concept of analogy and how to how to graphically represent analogy; • the concept of numerical powers and the power of 10.	**Lab availability:** • no labs • no labs • no labs • no labs • no labs • no labs • no labs
11 -12	**Pupils are expected to know:** • how to read, write and order all natural, fractional and decimal numbers plus carry out all possible calculations.	**Lab availability:** • yes, but partly, see the labs mentioned above

Table A2: Labs that correspond to the mathematics topic area: measurement

Age	Measurement	Availability of labs on the Go-Lab sharing platform
5 - 6	**Pupils learn:** • to measure, compare, describe and solve simple practical problems for: lengths and heights, capacity and volume, time; • recognise and know the value of different denominations of coins and notes; • recognise and use language relating to dates, including days of the week, weeks, months and years; • tell the time (including time frames: half past the hour, quarter to, etc.); draw the hands on a clock face to demonstrate and recognise them; • recognise and name basic shapes (circle, rectangle, square, triangle)	**Lab availability:** • yes, Area Builder, but no labs for capacity and time • no labs • no labs • no labs • no labs
6 - 7	**Pupils learn:** • choose and use appropriate standard units to estimate and measure: length/height (m/cm); mass (kg/g); temperature (°C), capacity (litres/ml) to the nearest appropriate unit, using rulers, scales, thermometers and measuring vessels; • compare and order lengths, mass, volume/capacity and record the results using >, < and =	**Lab availability:** • no labs • no labs
7 - 8	**Pupils learn:** • the concept of volume; • how to estimate and then measure the perimeter and area of a rectangular and square; • to recognise the relation between time units i.e. 1 day = 24 hours, 1 hours = 60 minutes) the relation among the various coins and notes.	**Lab availability:** • yes, Area Builder • yes, Area Builder • no labs

Age	Measurement	Availability of labs on the Go-Lab sharing platform
8 - 9	**Pupils learn:** • how to use the correct measurement units for length, volume and capacity • the relation between the different length units • how to calculate the volume of a rectangular prism • how to calculate the perimeter and the area of rectangular and right triangle • how to write monetary amounts in decimal form; • the concepts of year, decade and century; • how to solve problems using the concepts of time (hour, minutes, seconds)	**Lab availability:** • no labs • no labs • no labs • no labs • yes, Unit Rates • no labs • no labs
9 - 10	**Pupils learn:** • how to use the correct measurement units for length, volume and mass; • conversions between the different units; • how to calculate the area and perimeter of rectangular, square and triangles with the use of formulas; • solve problems involving converting between units of time; • how to measure angles using the right tools.	**Lab availability:** • no labs • no labs • yes, Area Builder, but not for triangles • no labs • yes, Trig Tour
10 - 11	**Pupils learn:** • how to calculate the area of a parallelogram and the extended area of three dimensional objects ; • about the summary of polygon angles; • solve problems involving the calculation and conversion of units of measure, using decimal notation up to three decimal places; • use, read, write and convert between standard units; • calculate, estimate and compare volume of cubes and cuboids using standard units, including cubic centimetres (cm3) and cubic metres (m3), and extending to other units [for example, mm3 in km3].	**Lab availability:** • no labs • no labs • no labs • no labs • no labs
11 -12	**Pupils:** • are reminded how to use the various measurement units and how to use them in day to day life; • learn how to compose a rule for a simple numerical and geometric motif	**Lab availability:** • no labs • no labs

Table A3: Labs that correspond to the mathematics topic area: geometry

Age	Geometry	Availability of labs on the Go-Lab sharing platform
5 - 6	**Pupils learn:** • how to describe the position and direction of movement of an object; • how to recognise and name the basic two dimensional and three dimensional objects	**Lab availability:** • yes, Forces And Motion: Basics • no labs
6 - 7	**Pupils learn:** • the basic properties of rectangular and square how to identify and name the different angles • three dimensional objects and associate them with their environment; • are introduced to the concept of symmetry.	**Lab availability:** • no labs • no labs • no labs
7 - 8	**Pupils learn:** • to identify the various polygons; • to identify three dimensional shapes (i.e. cone; cylinder, sphere, pyramid etc.); • to name the different types of angles; • the four cardinal directions (north, south, east, west).	**Lab availability:** • no labs • no labs • no labs • no labs
8 - 9	**Pupils learn:** • practice on designing, reproducing and recognising different shapes and their properties • the concepts of facet, right angle, vortex, edge; • how to complete the symmetry of a shape; • describe positions on a two dimensional grid as coordinates in the first quadrant; • describe movements between positions as translations of a given unit to the left/right and up/down; • plot specified points and draw sides to complete a given polygon.	**Lab availability:** • no labs • no labs • no labs • yes, Graphing Lines • no labs • no labs
9 - 10	**Pupils learn:** • the design on three dimensional shapes using the appropriate methodology • how to calculate the perimeter of different shapes	**Lab availability:** • no labs • yes, Area Builder for two dimensional shapes, but no labs three dimensional shapes
10 - 11	**Pupils learn:** • about the properties of triangles and their secondary elements i.e. median, altitude; • the properties of circles; to recognise, classify and construct two and three dimensional shapes by using the appropriate instruments	**Lab availability:** • no labs • yes, Trig Tour for circles and Area Builder for two dimensional shapes
11 -12	**Pupils:** • are reminded how to use the various measurement units and how to use them in day to day life; • learn how to calculate the perimeter and area of a circle plus the areas and volumes of three dimensional objects learn how to reproduce, draw and compare different angles • learn how to scale images up or down	**Lab availability:** • no labs • yes Trig Tour for angles, but no labs for perimeter and area of circles and three dimensional shapes • no labs

Table A4: Labs that correspond to the mathematics topic area: algebra

Age	Algebra	Availability of labs on the Go-Lab sharing platform
5 - 6	**Pupils learn:** • how to sort different simple objects by using certain criteria; • the concept of equality and inequality.	**Lab availability:** • yes, Fraction Matcher • no labs
6 - 7	**Pupils learn:** • how to solve equations by using the concepts of equality and inequality, by calculating the value of x	**Lab availability:** • yes, Expression Exchange
7 - 8	**Pupils learn:** • how to classify events as certain, possible and impossible to happen	**Lab availability:** • no labs
8 - 9	**Pupils learn:** • how to recognise numerical patterns and build on them	**Lab availability:** • no labs
9 - 10	**Pupils learn:** • how to describe patterns and investigate the relations among different patterns; • how to create graphs, about the minimum, maximum and average value	**Lab availability:** • no labs • yes, Graphing Lines for graphs, but no labs for minimum, maximum, and average value
10 - 11	**Pupils learn:** • how express powers; • how to simplify mathematical expressions; • how to solve equations; • about the priorities in performing the various calculations.	**Lab availability:** • no labs • yes, Expression Exchange • no labs • no labs
11 -12	**Pupils are expected to know:** • how to solve equations;	**Lab availability:** • no labs

7. Appendix B: Science topics and labs

Table B1: Labs that correspond to the science topic area: materials, processes, and states of matter

Age	Materials, processes, and states of matter	Availability of labs on the Go-Lab sharing platform
5 to 6	**Pupils learn:** • To distinguish between an object and the material from which it is made. • To identify and name a variety of everyday materials, including wood, plastic, glass, metal, water, and rock. • How to identify solid, liquid and gas objects.	**Lab availability:** • no labs • no labs • yes, states of matter labs: Phase Change (3 labs) and States Of Matter: Basics
6 to 7	**Pupils learn :** • To study and experiment with daily materials (e.g., sugar, salt, wood, and clay) and classify materials according to their characteristics; • To identify and compare the suitability of everyday materials, including wood, metal, plastic, glass, brick, rock, paper and cardboard for particular uses; • To distinguish between solids and liquids and perceive changes in states of matter. • To do simple experiments with water: capacity and volume, physical properties, recognition of floating materials, etc. • About basic types of energy • About energy and the human body, everyday habits and energy consumption at school and home. • About energy saving and about alternative source of energy	**Lab availability:** • yes, the buoyancy labs: Archimedes' Principle, Buoyant Force In Liquids, Density And Buoyancy, Force Buoyancy, Splash: Virtual Buoyancy Laboratory, and Weblab-Deusto Aquarium, and the heat labs: Convection: Forced/Natural Convection, and Heat Transfer, but no labs for weight/mass, volume, and magnetic conductivity • no labs • yes, states of matter labs • yes, the buoyancy labs • yes, Balloon And Static Electricity, Energy loss, Forces And Motion: Basics, Mechanical/Electrical Equivalent Of Heat, Newton's Cradle, Solar Lab, and Windmill Lab • no labs • yes, Solar Lab and Windmill Lab
7 to 8	**Pupils learn:** • Simple experiments and observations with common daily materials, studying their properties (e.g., flexibility, resistance, solubility, and transparency). • To compare and group together different kinds of rocks and to describe how fossils are formed. • To recognise that soils are made from rocks and organic matter. • To recognise light and darkness, shadows and its relation to light	**Lab availability:** • no labs • no labs • no labs • yes, Findmyshadow, Motions Of The Sun Simulator, and Sun Shadow Visualizer, but no labs for light and darkness

Age	Materials, processes, and states of matter	Availability of labs on the Go-Lab sharing platform
	• To do simple experiments with air (e.g., balloons and syringes) and recognize properties of air (e.g., weight and temperature) and air's effects on different objects.	• no labs
8 to 9	**Pupils learn:** • About different physical phenomena, including materials change of state when they are heated or cooled. • About evaporation and condensation in the water cycle. Association of the rate of evaporation with temperature. • About mixtures and solutions • To Compare how things move on different surfaces • Learn the basics about magnetic forces (how magnets attract or repel each other, etc.). • To do simple experiments with light and magnets. • Basic mechanics and results of simple experiments with levers, pulleys, springs, and elastic materials. • identify how sounds are made; • recognise that vibrations from sounds travel.	**Lab availability:** • yes, states of matter labs • no labs • no labs • yes, friction labs: Friction (2 labs) and Friction Lab • no labs • no labs • yes, Balancing Act, Double Mass-Spring, Elastic Lab, Equilibrium Of Three Forces, Horizontal Oscillation, Mass And Spring, Pulleys, Seesaw Lab, and Single Spring • no labs • yes, Beats, Doppler, Guitar String Wave, and Wave On A String
9 to 10	**Pupils learn:** • To compare and group together everyday materials on the basis of their properties, including their hardness, solubility, transparency, conductivity (electrical and thermal), and response to magnets. • To know that some materials will dissolve in liquid to form a solution, and describe how to recover a substance from a solution. • To demonstrate that dissolving, mixing and changes of state are reversible changes. • About climate zones and greenhouse effect • About the water cycle and how groundwater and water springs develop. Consequences of lakes, rivers, sea pollution. • About energy production and how it impacts the environment • About the use of renewable sources of energy • About the use of nuclear energy; green energy; use of biomass; photovoltaic and wind power. • About the force of gravity acting between the earth and a falling object	**Lab availability:** • yes, the buoyancy labs, but no labs for hardness, solubility, transparency, conductivity (electrical and thermal, and response to magnets • no labs • yes, see states of matter labs, but no labs for dissolving and mixing • yes, Sunlight, Infrared, Co2 And The Ground, but no labs for climate zones • no labs • yes, Air Pollution • yes, Solar Lab and Windmill Lab • yes, Solar Lab and Windmill Lab, but no labs for nuclear energy, green energy, and use of biomass • yes, Gravity Drop Lab, Gravity Force Lab, and Atwood Machine

Age	Materials, processes, and states of matter	Availability of labs on the Go-Lab sharing platform
	• To identify the effects of air resistance, water resistance and friction, that act between moving surfaces. • To recognise that some mechanisms, including levers, pulleys and gears, allow a smaller force to have a greater effect. • About management of solid and other types of waste. • About energy saving techniques, maintenance of natural resources and organic waste.	• yes, friction labs, but no labs for air and water resistance • yes, Balancing Act, Equilibrium Of Three Forces, Gearsketch, Pulleys, and Seesaw Lab • no labs • no labs
10 to 12	**<u>Pupils learn:</u>** • About basic characteristics of objects (mass, volume, density). • About molecules and how they affect different objects' characteristics. • To describe electricity related phenomena by using molecules • To recognise motion • To define forces and how they are applied • About acids and their properties. • To recognise that light appears to travel in straight lines. • how energy is never lost and how it changes forms and it is stored; • about current energy sources and the need for their conscious use; • about the relation between electricity and magnetism; • about ardency.	**<u>Lab availability:</u>** • yes, buoyancy labs • yes, molecule labs: Boiling Point, Diffusion, Diffusion Across A Permeable/Semipermeable Membrane, Diffusion And Temperature, Intermolecular Attractions And State Of Matter, Kinetic Molecular Theory Ii, Molecular View Of A Gas/Liquid/Solid, Molecule Shapes, Molecule Shapes: Basics, Molecules And Light, Oil And Water, One Dimensional Gas, Pressure, Pressure Equilibrium, Reactants, Products And Leftovers, The Number-Volume Relationship, Thiosulphate, and Seeing Intermolecular Attractions • no labs • yes, motion labs: Atwood Machine, Balancing Act, Basketball Ball, Billiards, Circular Friction Test Track, Coupled Pendula, Curling Stone Momentum, Double Mass-Spring, Elastic Lab, Equilibrium of Three Forces, Force Direction Relative To Motion, Foucault Pendulum, Friction (2 labs), Friction Lab, Gearsketch, Graphing Of Motion Lab, Gravity Drop Lab, Gravity Forces Lab, Horizontal Oscillation, Impulse, Mass And Spring, Newton's Law Lab With Photogates, Newton's Mountain Canon, Oscillation (2 labs), Pendulum (2 labs), Pendulum Lab (2 labs), Pendulum Simulation, Projectile Motion (2 labs), Pulleys, Reflecting Waves, River Crossing Lab, Satellite, Seesaw Lab, Simple Pendulum, Single Spring, and Stopping Distance Test Track • yes, motion labs and Forces And Motions : Basics • no labs • yes, light labs: Bending Light, Color Vision, Lens, Refraction, Spectrum, The Color Of The Light, and The Way A Concave/Convex Mirror Works • yes, Balloons And Static Electricity, Energy Loss, Forces And Motion: Basics, John Travoltage, Mechanical/Electrical Equivalent Of Heat, Newton's Cradle, Solar Lab, and Windmill Lab • no labs • yes, Faraday's Law • no labs

Table B2: Labs that correspond to the science topic area: space and time

Age	Space and time	Availability of labs on the Go-Lab sharing platform
5 to 6		
6 to 7	**Pupils learn:** • To identify the alternation of day and night, weeks, months, and seasons. To use tools for tracking and measuring time. • To discover and memorize particular points of reference in time and the relation between sun's position in the sky and the rotation from day to night. • To observe changes across the four seasons;	**Lab availability:** • yes, Motion Of The Sun Simulator and Seasons And Ecliptic Simulator, but no labs for tools for tracking and measuring time • yes, Motion Of The Sun Simulator, Seasons And Ecliptic Simulator, and Suncalc • yes, Motion Of The Sun Simulator and Seasons And Ecliptic Simulator
7 to 8	**Pupils learn:** • How to relate different weather conditions with the different seasons and a place's geographical position.	**Lab availability:** • no labs
8 to 9	**Pupils learn:** • The sky and earth. In particular, about the movement of earth (and the other planets) around the sun, earth's rotation, the length of day, and how it changes with the seasons, the movement of the moon around earth) • About volcanoes and earthquakes, and the risks they present to human societies.	**Lab availability:** • yes, Lunar Phase Simulator, Motion Of The Sun Simulator, Planets, Rotating Sky Explorer, Seasons And Ecliptic Simulator, Spin Simulator, The Faulkes Telescope Project, and Worldwide Telescope • no labs
9 to 10	**Pupils learn:** • In astronomy, students learn about earth's shape, the moon's phases, and the locations of earth and the moon in the solar system.	**Lab availability:** • yes, see previous labs and Structure Of The Atmosphere
10 to 11/12		

Table B3: Labs that correspond to the science topic area: plants and nature

Age	Plants and nature	Availability of labs on the Go-Lab sharing platform
5 to 6	**Pupils learn:** • To identify and name a variety of common plants. • To identify tree parts. • Basic concepts related to forests (i.e. air, soil, branches, stem, roots, leaves, flora, fauna etc.).	**Lab availability:** • no labs • no labs • no labs
6 to 7	**Pupils learn:** • To identify different habitats. • To observe and describe how seeds and bulbs grow into mature plants and describe how plants need water, light and a suitable temperature to grow and stay healthy. • To identify and describe the basic structure of a variety of common flowering plants, including trees.	**Lab availability:** • no labs • yes, Photolab and Plant Mineral Nutrition, but no labs for how seeds and bulbs grow into mature plants • no labs
7 to 8	**Pupils learn:** • Levels and basic characteristics of biodiversity and factors threatening biodiversity. • Rare and endangered plants and animals. • To identify and describe the functions of different parts of flowering plants: roots, stem/trunk, leaves and flowers. • To explore the requirements of plants for life and growth (air, light, water, nutrients from soil, and room to grow) and how they vary from plant to plant. • To explore the part that flowers play in the life cycle of flowering plants, including pollination, seed formation and seed dispersal.	**Lab availability:** • no labs • no labs • no labs • yes, Photolab and Plant Mineral Nutrition • no labs
8 to 9	**Pupils learn:** • About food chains and food webs; • About the evolution of an environment managed by humans (e.g., forests) and the importance of biodiversity. • To compare and classify plants according to some criteria (e.g., type and colour of flowers, leaf and root shapes, edible and inedible plants). • To explore and use classification keys to help group, identify and name a variety of living things in their local and wider environment • To recognise that environments can change and that this can sometimes pose dangers to living things.	**Lab availability:** • no labs • no labs • no labs • no labs • no labs
9 to 10	**Pupils learn:** • About national parks and protected areas • About changes in biodiversity, introduction of new species, extinction of species. • To continue to learn about recognition classification systems related to biodiversity • Further explanations about the classification of species and organisms • About environmental imbalances due to human activities.	**Lab availability:** • no labs • no labs • no labs • no labs • yes, Air Pollution and Carbon Stabilization Wedges
10 to 11/12	**Pupils learn:** • About cells as the basic unit of life. • About the hierarchical organization of living organisms. • About microorganisms and their relation to hygiene and social problems.	**Lab availability:** • no labs • no labs • no labs

Table B4: Labs that correspond to the science topic area: animals and humans

Age	Animals and humans	Availability of labs on the Go-Lab sharing platform
5 to 6	**Pupils learn:** • To identify and name a variety of common animals including fish, amphibians, reptiles, birds and mammals. • To recognize and identify physical characteristics of the body, sexual identity, parts of the body, and comparison with other children, parents, brothers, and sisters. • To identify, name, draw and label the basic parts of the human body and say which part of the body is associated with each sense.	**Lab availability:** • no labs • no labs • no labs
6 to 7	**Pupils learn:** • To identify and name a variety of common animals that are carnivores, herbivores and omnivores; • To describe and compare the structure of common animals (fish, amphibians, reptiles, birds and mammals). • Find out about and describe the basic needs of animals, including humans, for survival (water, food and air); • Students learn about the basic characteristics of the human body and about health habits and how they can promote good health; • Students identify the characteristics of living things (i.e., birth, growth, and reproduction), and nutrition and animal diets. They understand the interactions between living things and their environment, and they learn to respect the environment; • Explore and compare the differences between things that are living, dead, and things that have never been alive;	**Lab availability:** • no labs • no labs • no labs • no labs • no labs • no labs
7 to 8	**Pupils learn:** • About stages and conditions of development of a living thing, including breeding patterns and factors affecting the development of plants and animals. • An introduction to the classification of living things—similarities and differences of interpretation of species and kinships. • To describe how animals obtain their food from plants and other animals, using the idea of a simple food chain. • To identify that humans and some other animals have skeletons and muscles for support, protection and movement.	**Lab availability:** • no labs • no labs • no labs • no labs
8 to 9	**Pupils learn:** • About the functioning of the human body and health. Describe the simple functions of the basic parts of the digestive system in humans. • Continue to learn about body movement (muscles, bones, and joints); • Introduction to metabolic functions—digestion, breathing, and blood circulation; • About human reproduction and sex education; • To construct and interpret a variety of food chains, identifying producers, predators and prey.	**Lab availability:** • no labs • no labs • no labs • no labs • no labs

Age	Animals and humans	Availability of labs on the Go-Lab sharing platform
9 to 10	**Pupils learn:** • Living things and their habitats. Study of bones and skeletal structure and its functions, the study of the muscular system and its functions, and the study of the skin and its functions. • To describe the differences in the life cycles of a mammal, an amphibian, an insect and a bird • To describe the life process of reproduction in some plants and animals. • To describe the changes as humans develop to old age.	**Lab availability:** • no labs • no labs • no labs • no labs
10 to 11/12	**Pupils learn:** • To further the knowledge about how living things are classified into broad groups according to common observable characteristics and based on similarities and differences, including microorganisms. • About adaptation of animals and how this may lead to evolution. • To identify and name the main parts of the human circulatory system, and describe the functions of the heart, blood vessels and blood. • The impact of diet, exercise, drugs and lifestyle on the way their bodies function.	**Lab availability:** • no labs • no labs • no labs • no labs

Table B5: Labs that correspond to the science topic area: other topics

Age	Other topics	Availability of labs on the Go-Lab sharing platform
5 to 6		
6 to 7	**Pupils learn:** • How time is measured and to get familiar with the use of vocabulary and expressions around it.	**Lab availability:** • no labs
7 to 8	**Pupils learn:** • Orientation	**Lab availability:** • no labs
8 to 9	**Pupils learn:** • To identify common appliances that run on electricity; • To construct a simple series electrical circuit • To recognise some common conductors and insulators, and associate metals with being good conductors. • Electrical circuit, identifying and naming its basic parts, including cells, wires, bulbs, switches and buzzers	**Lab availability:** • no labs • Power Of A Light Bulb and Simple Circuit • no labs • no labs
9 to 10		
10 to 11/12	**Pupils learn:** • To compare and give reasons for variations in how components function, including the brightness of bulbs, the loudness of buzzers and the on/off position of switches. • To use recognised symbols when representing a simple circuit in a diagram.	**Lab availability:** • Power Of A Light Bulb and Ohm's Law • no labs