GO-LAB ECOSYSTEM: USING ONLINE LABORATORIES IN A PRIMARY SCHOOL

O. Dziabenko[1], O. Budnyk[2]

[1] University of Deusto (SPAIN)
[2] Vasyl Stefanyk Precarpathian National University (UKRAINE)
olga.dziabenko@deusto.es, olena.budnyk@pu.if.ua

Abstract

Online (virtual and remote) experiments are the essential part of the contemporary science, technology, engineering and mathematics (STEM) education. Although online experiments are broadly employed in higher and secondary school class instructions, they should still be presented in a primary school to teachers, education administration, and designers such as curriculum developers and assessment creators. This paper focuses on the planning and embedding online laboratories into primary school science curriculum. The challenges of implementation of different types of laboratories in a practical context are discussed as well. The integration of the laboratories is demonstrated using the Go-Lab ecosystem. The ecosystem consists of more than 600 online laboratories, 40 inquiry applications, 940 inquiry learning spaces (ILS) that are presented with more than 30 languages (as at the time of writing this paper). Moreover, the Go-Lab platform supports teachers to realize science education by offering interactive domain-related applications that enable inclusive, active and engaged learning, providing students with tools that support these forms of learning and train 21st century skills such as digital literacy, computational thinking, research culture, and creativity. The modernization of the school education encourages teachers to start modelling such students skills from their very early age. The paper shows all phases of embedding the laboratories into the inquiry environment. It describes several demanded activities that a teacher shall perform. It includes (1) mapping the lesson; (2) defining the lesson goals where the lab will be used; (3) establishing the type of the online experiments that should be embedded; (4) defining critical points of the usage of the experiment; (5) creating usage guide in a language suitable for the student age. The authors believe that the paper will be useful for primary school teachers as well as for developers of the online laboratories for elementary school students.

Keywords: Inquiry Based Science Education, Innovative Educational Technologies, Inquiry Learning Space, online laboratories, Go-Lab ecosystem, primary school.

1 INTRODUCTION

As a response to a shortage of science-knowledgeable people [1], the society becomes more and more engaging with STEM [2]. Hands-on laboratory practice is a critical component in the training instructional design of the lessons across all areas of study, beginning with kindergarten and continuing through post-secondary education. Research has shown that students with laboratory experience develop problem-solving and critical-thinking skills [3], as well as gain exposure to phenomena, materials, and equipment in a lab setting. At the same time, one of the main challenges in primary education is a conduct of the 'hands-on' laboratory practices taking in account large classes and safety priorities. Therefore, in recent years, blended science learning in primary school education has gained popularity as an innovative method to engage pupils in a safe active learning context. The blended learning ensures an inclusion and equity in education and increases employment of distance delivery modes for teaching to kids at various geographic locations and learning styles, in which online (virtual and remote) experiment is the essential part.

Virtual and remote labs offer many advantages for primary school teachers over hands-on laboratories. We would like to mention some of them:

- an introduction of the top-notch ICT developments and apps in the educational process and, therefore, increasing students interest in the scientific world;
- saving resources - no need in purchasing expensive equipment and materials;
- a design and visualization of scientific processes that is basically impossible in laboratory settings;

- an observation of experiment processes in great detail and at different timescales;
- a safety during the work with dangerous materials and/or devices;
- a rapid implementation of series of experiments with different input parameters;
- real-time feedback;
- rapid control of student learning progress;
- offering scientific experiments in an inclusive class with children with different learning styles;
- simultaneous application of a large number of students to the same experiment or laboratory;
- conducting an experiment many times (at the student's request) 24 hours a day, 7 days a week, and so forth.

Although one could assume that such an exciting tool should be used by primary school teachers widely, unfortunately, it is not quite so. From one side, the school teachers do not have enough time and support for merging and implementing contemporary methods such as flipped learning, problem-based, game-based and inquiry-based learning and so on, with online laboratories in their lesson instructions. From the other side, most of the existing online laboratories are created for the K12+ students, making their application in primary school even more complicated. In order to introduce to the teachers the full cycle of virtual laboratories incorporation in the lesson, we use Go-Lab ecosystem [4].

To solve the above described problems, several visionary workshops were organized, the main task of which was planning, designing and building the teaching modules using Inquiry-Based Scientific Education (IBSE) approach in consolidation with online laboratories. The authors believe that such activities can encourage teachers to use created learning materials and modules in their classes. In the paper, the vital milestones of the IBSE implementation in lesson structure (Inquiry Learning Spaces) using Go-Lab platform are presented. The first part is devoted to the description of the Go-Lab ecosystem and advantages of using it in the primary school. The main steps of embedding the laboratories into the inquiry environment and several demanded activities that a teacher shall perform are presented in the second part. A brief description of how to make virtual laboratory and inquiry module efficient is included. The good examples of the Go-Lab repository will be shown. The conclusion will introduce the main findings and future activity.

2 GO-LAB ECOSYSTEM: INQUIRY BASED SCEINCE EDUCATION

The Go-Lab ecosystem is the largest collection of online labs, interactive inquiry apps, and Inquiry Learning Spaces (ILS), also known in the literature as the Inquiry Learning Modules. This platform (online ecosystem) contains more than 600 online laboratories, 40 applications, and 990 ILSs in more than 30 world languages (as at the time of writing this paper). Teachers can combine online labs and apps into Inquiry Learning Spaces, share these with their colleagues and students, and, as a result, attract pupils of all ages to online research, to create and test their own hypotheses, and to design STEAM educational games.

The ecosystem offers the incorporated pedagogical scaffold for IBSE approach, which has been widely used in teaching science subjects over the last decade. This method enforces independent acquisition of knowledge, the search for scientific information, formulating hypotheses, and building and performing experiments and activities to prove or reject these hypotheses. "Many state and federal governments have mandated in such documents as the National Science Education Standards that inquiry strategies should be the focus of the teaching of science within school classrooms" [5]. Moreover, "inquiry experiments can provide valuable opportunities for students to improve their understanding of both science content and scientific practices" [6].

The Go-Lab ecosystem offers Inquiry Learning Cycle incorporated in the lesson structure. The Inquiry Learning Cycle [7] specifies the steps of an inquiry learning process. This cycle contains five main inquiry sequences: Orientation, Conceptualization, Investigation, Conclusion and Discussion (Fig.1).

Briefly, Orientation phase intends to stimulate interest and curiosity about a lesson topic and to address a learning challenge through a problem statement. At Conceptualization phase students start to build research task generating hypotheses and research questions based on the stated in Orientation phase problem. The Investigation is devoted to activities such as exploration, experimentation, and data collection and interpretation. In the next phase, Conclusion, students design the conclusions based on the data obtained, compare the experimental findings and their stated previously hypothesis as well as write a scientific report. The Discussion sequence encourages students to present outcomes of an inquiry phase or of the entire inquiry cycle and discuss them with classmates. The Discussion is also the phase where students can either connect the performed science experiment with real-life situations, e.g. local community challenges, or plan and dig up further additional research with a set of questions.

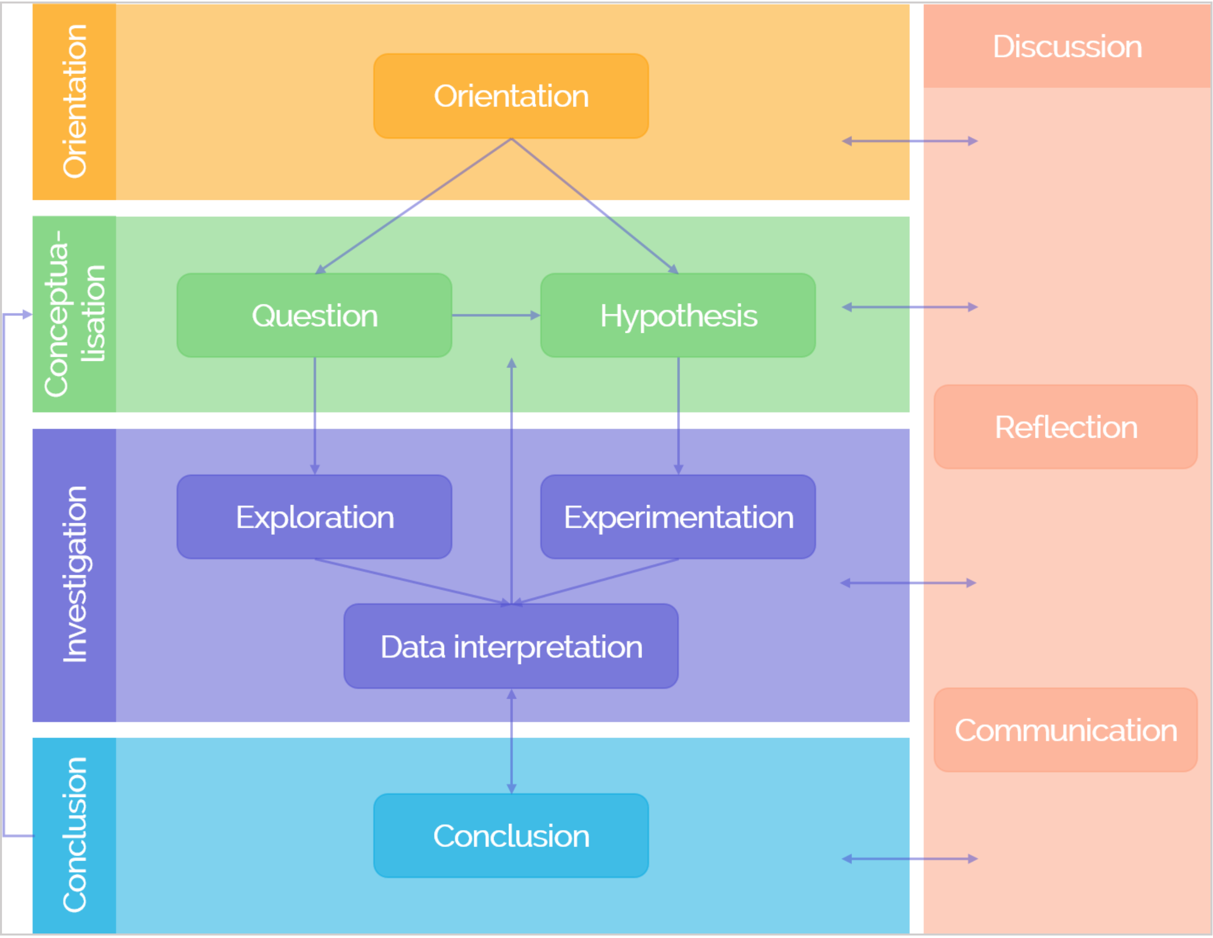


Figure 1. Go-Lab Inquiry Learning Cycle.

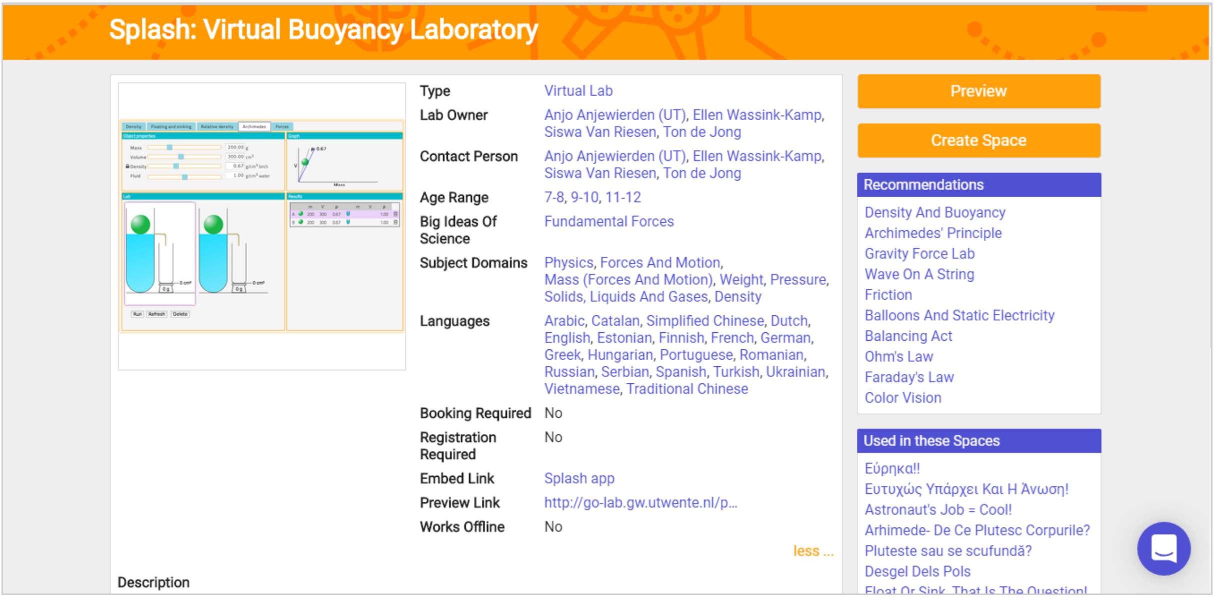
The Go-Lab ecosystem represents the basic scenario of Inquiry Learning Cycle used to create ILSs. However, a teacher can decide which phases to include into his/her ILS and what Pedagogical scenarios (“Better by mistake” [8], “Six Thinking Hats” [9], etc.) to use.

In most cases, the Inquiry is used for studying STEM subjects in secondary and high schools. In today's requirements of educational reforms in many countries (especially the post-Soviet states), the questions of research culture and creativity of students, critical and computational thinking, and digital literacy development starting with elementary school are arising [10]. In this article, we present the methodological aspects applying IBSE with online laboratories teaching science topics in a primary classroom. The research shows that the guided-inquiry laboratory experiments had much more effect on students' academic achievement than the traditional teaching method [11], [12]. "Laboratory experiments which are inquiry-based learning supports students apply their knowledge; understand real world situations and supports discovery scientific facts and principles. In inquiry based learning environments, students are more active and they guiding their own learning processes" [13].

3 GO-LAB ECOSYSTEM: ONLINE LABORATORIES

For elementary school, Go-Lab ecosystem offers 263 out of 600 online laboratories for exploring various phenomena in physics, chemistry, geography, astronomy, etc. We selected several to show the best practice of creating online laboratories for the elementary school and, at the same time, to highlight the challenges of the design and development.

For example, in "Splash: Virtual Buoyancy Laboratory" (Fig.2) students can design research objects using their properties such as mass, volume, and density, and drop these objects into a tube filled with a liquid. Additionally, students can select a density of the liquid. This allows the student to find a link between object motion and liquid density. Moreover, students can measure the level of liquid displaced by the object and “discover” the Archimedes’ Principle [14]. The good example of use this laboratory in inquiry space is ILS “Floating and Sinking” [15].



Splash: Virtual Buoyancy Laboratory

Type	Virtual Lab
Lab Owner	Anjo Anjewierden (UT), Ellen Wassink-Kamp, Siswa Van Riesen, Ton de Jong
Contact Person	Anjo Anjewierden (UT), Ellen Wassink-Kamp, Siswa Van Riesen, Ton de Jong
Age Range	7-8, 9-10, 11-12
Big Ideas Of Science	Fundamental Forces
Subject Domains	Physics, Forces And Motion, Mass (Forces And Motion), Weight, Pressure, Solids, Liquids And Gases, Density
Languages	Arabic, Catalan, Simplified Chinese, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Portuguese, Romanian, Russian, Serbian, Spanish, Turkish, Ukrainian, Vietnamese, Traditional Chinese
Booking Required	No
Registration Required	No
Embed Link	Splash app
Preview Link	http://go-lab.gw.utwente.nl/p...
Works Offline	No

less ...

Description

Recommendations

- Density And Buoyancy
- Archimedes' Principle
- Gravity Force Lab
- Wave On A String
- Friction
- Balloons And Static Electricity
- Balancing Act
- Ohm's Law
- Faraday's Law
- Color Vision

Used in these Spaces

- Εύρηκα!!
- Ευτυχώς Υπάρχει Και Η Άνωση!
- Astronaut's Job = Cool!
- Arhimede- De Ce Plutesc Corpurile?
- Pluteste sau se scufundă?
- Desgel Dels Pols
- Float Or Sink, That Is The Question!

Figure 2. Splash: Virtual Buoyancy Laboratory (screenshot).

The goal of the Electricity theme of elementary school learning is to describe and draw models for common static electricity concepts (static electricity, transfer of charge, induction, attraction, repulsion, and grounding). Interactive simulation (Fig. 3) helps students to reach this goal [16]. Experimenting kids rub a balloon on a sweater and then release it. The balloon flies over and sticks to the sweater. Students can perform this procedure many times; and every time, it proves the static electricity concept. The good example of use this laboratory in inquiry space is ILS “Staatiline Elekter” [17].

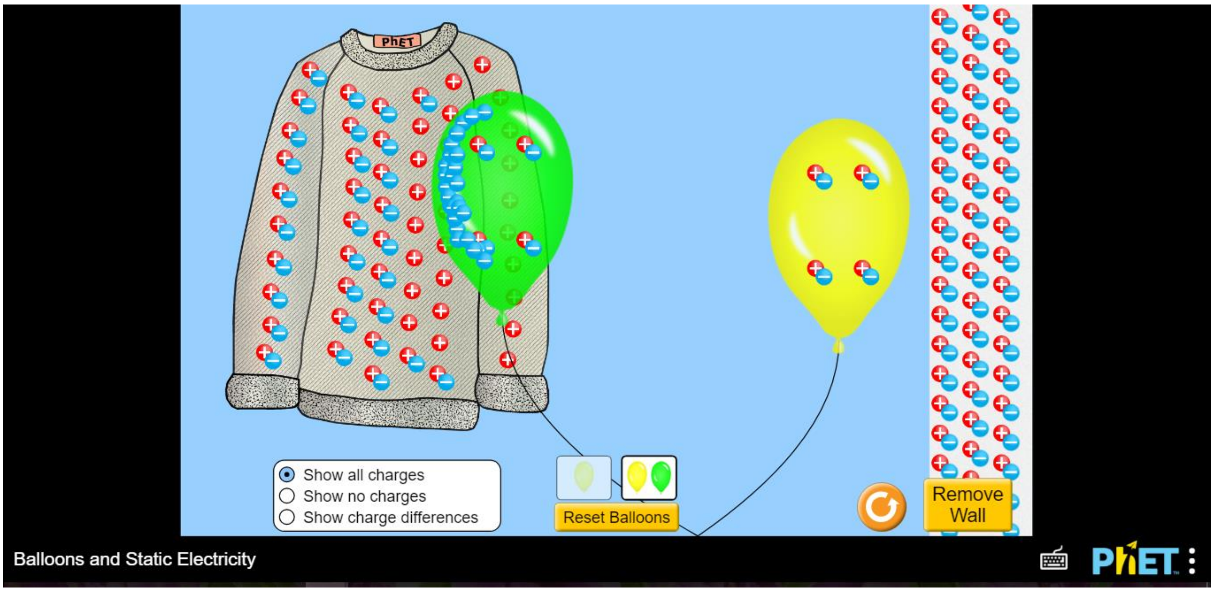
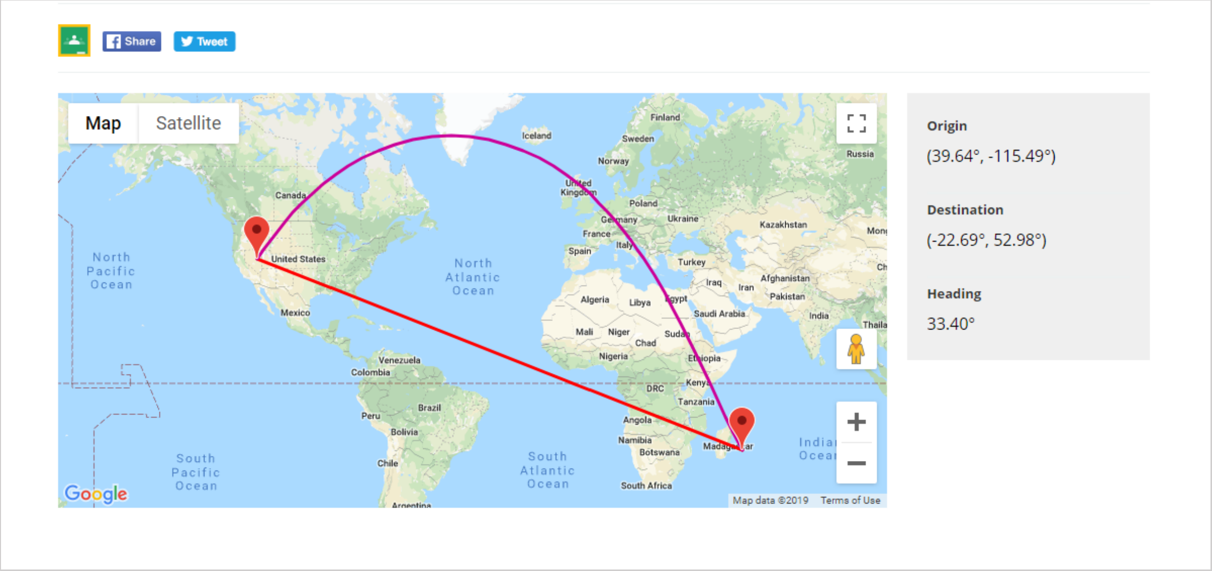


Figure 3. Balloons and Static Electricity Laboratory (screenshot).

The "Geodesics" online laboratory (Fig. 4) helps pupils of elementary school to understand a geodesic concept - a curve representing the shortest path between two points on a surface. In real-life approach, kids can think of it as a route that a bird (or an airplane) would fly to get from one point to another (any wind effect should be ignored) [18].



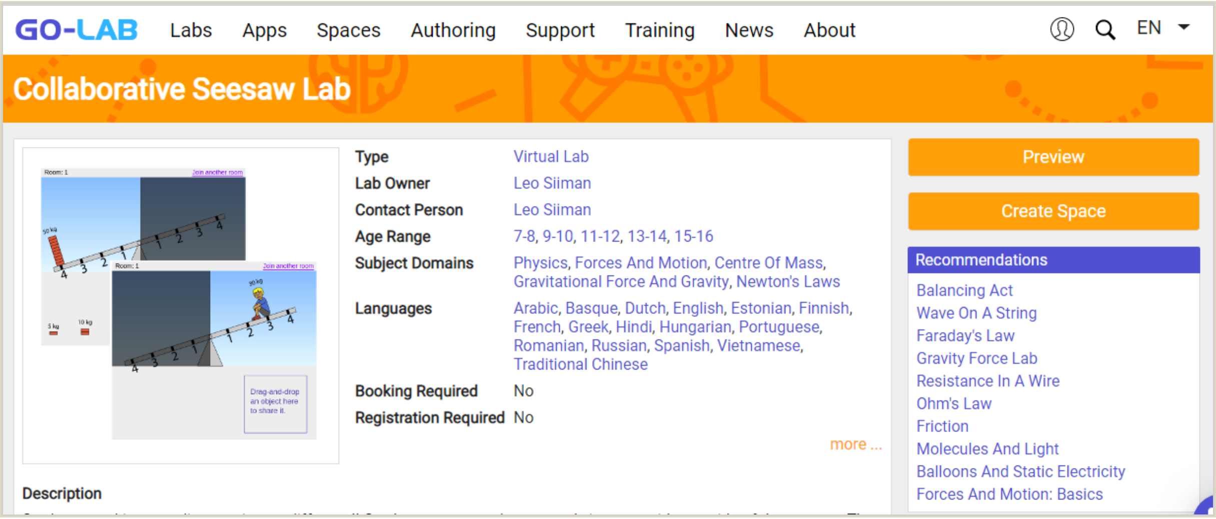
Origin
(39.64°, -115.49°)

Destination
(-22.69°, 52.98°)

Heading
33.40°

Figure 4. Geodesics laboratory (screenshot).

Another interesting example of the online laboratory is Collaborative Seesaw Lab (Fig. 5). The laboratory, devoted to pupils of 7-10 years old, aims simultaneously at understanding of how a seesaw works and promoting collaborative problem-solving skills [19]. Two students working at a distance share an online seesaw, where each student can only interact with one (either left or right) side of it. They place objects of different masses onto four different positions on their side of the seesaw. They can also pass objects back and forth between each other. Two ILSs should be designed for each side of the seesaw, e.g., “How Does a Seesaw Work? - Version A” [20] is for its left side, and “How Does a Seesaw Work? - Version B” [21] is for the right side.



Collaborative Seesaw Lab

Type	Virtual Lab
Lab Owner	Leo Siiman
Contact Person	Leo Siiman
Age Range	7-8, 9-10, 11-12, 13-14, 15-16
Subject Domains	Physics, Forces And Motion, Centre Of Mass, Gravitational Force And Gravity, Newton's Laws
Languages	Arabic, Basque, Dutch, English, Estonian, Finnish, French, Greek, Hindi, Hungarian, Portuguese, Romanian, Russian, Spanish, Vietnamese, Traditional Chinese
Booking Required	No
Registration Required	No

Recommendations
- Balancing Act
- Wave On A String
- Faraday's Law
- Gravity Force Lab
- Resistance In A Wire
- Ohm's Law
- Friction
- Molecules And Light
- Balloons And Static Electricity
- Forces And Motion: Basics

Description

Figure 5. Collaborative Seesaw Lab (screenshot).

By checking the availability of online labs on Go-Lab ecosystem for the elementary school, we can figure out that out of 600 labs, 189 labs can be used to teach students of 9-10 years old, 53 ones – children of 7-8 years old and only 21 laboratories - kids under 7 years old. Therefore, the selection of the right laboratory that fits the students’ needs and levels of their knowledge is a nontrivial task.

In this research we use the strategy – employment of visionary workshops – created, tested and evaluated during the design and development of the remote experiment “Archimedes” [22],[23]. According to the teachers’ viewpoints collected during the visionary workshops, an online laboratory for primary school has to have the following characteristics:

- be scientifically correct, and at the same time, simple in presentation and related to real life and children's experience in order to be understandable for students of this age group;
- match to national curriculum of the elementary school;
- stimulate curiosity, creativity, critical thinking, and motivate to acquire a new knowledge in science;
- drawings, objects, steering should be clear and logical for kids such that they can begin and complete the experiment on their own;
- have balance between cognitive load and game components and features;
- have intuitively understandable instructions for conducting of experiments.

The pre-laboratory or pre-experiment videos and quizzes can help students to be better prepared for the laboratory and increase their understanding of the theories and concepts presented. The video or cartoon explanation can also be incorporated in different stages of experiment for comprehensive guide on laboratory procedures, important safety considerations as if it would be a real experiment, and waste disposal instructions if needed. Students watch video, e.g., on how to properly use a microscope, and solve quizzes before they start to conduct their experiment.

Also, it was mentioned that the main challenge of creating online laboratory for elementary science curricula lays in a visualization of simple and obvious things such as dissolution of substances in water, the qualitative and quantitative properties of materials (water, gas, glass, etc.).

4 GO-LAB ECOSYSTEM: ILS & VISIONARY WORKSHOPS

The Go-Lab ecosystem, being present already for four years in Europe, offers a large number (more or equal than 100) of ILSs in English (245 on the day of writing this text), Portuguese (106), Greek (112), and Romanian (100) languages. At the same time, East European countries such as Poland, Lithuania, Latvia, Hungary, Slovakia, Ukraine, and so on, in reforms of their school education system need such tool for implementing contemporary pedagogical science methodology in their teaching instructions. The visionary workshops programs have been developed to migrate Go-Lab ecosystem in the direction of Eastern Europe and adapt best practices of employment of IBSE at European schools in different languages. In this paper, we will present the results of work during several visionary workshops in Ivano-Frankivsk, Ukraine. The teachers of primary schools of Ivano-Frankivsk and its region participated.

From the beginning of the visionary workshops, the Go-Lab ecosystem in glance was introduced. According to the research, the online labs are the basis of any pedagogical scenario of Inquiry Learning Space [11]. In order to embed the online laboratories into the inquiry environment a teacher shall perform several demanded steps. These steps were carried out through the workshops.

The ILS design should begin with its *mapping*. A teacher should decide what physical or chemical processes will be explored, what parameters will be studied; what variables would be understandable for their students and how to introduce these variables in the ILS. Teacher should carefully think about the presentation of the chosen topic in the ILS to inspire his/her students. It could start with the orientation in the topic by storytelling, real-life examples or problems that are known and may be obvious to their students, activity refreshing previous knowledge, or even with an educational game. Teacher should keep in mind the students’ age and their level of knowledge. At this stage, it is critical to show students the significance of the learning topic for everyday life of their friends, families, and they own. Mapping the ILS, it would be helpful to write down possible challenges that can appear with formulating the hypothesis and research questions, with performing experiment, collecting data, and working on the conclusion. The guided questions on the conceptualization, conclusion and discussion stages could reduce and even eliminate students’ frustration and incorrect thinking. It would be beneficial to ask students to produce research report in a creative form such as drawings, clay crafts, songs, fairy tales, etc.

When the structure of the ILS is established, the *lesson goal* where the lab will be used should be defined. Teacher should set up the intended learning outcomes and their measurements. At this stage, based on prior job, teacher can *select an online experiment* that should be embedded. For elementary school students, a plan of the experiment *defining critical points* should be provided by a teacher with an explanation of a theoretical and practical context behind it, with possible errors that can happen, safety policy, etc. The video or cartoon *instruction* can help in this case. The guide and visual presentation should be in a language suitable for the student age.

Despite the difficulties in the presented above scheme to build the ILS, the process of the ILS producing and mastering is fun (according the feedback of the visionary workshop participants). On the Go-Lab repository [4] one can find numerous nicely created ILSs. Here we describe as an example two ILSs: “The adventures of the Droplet” (“Пригоди Крапельки”) and “Humans and Bees” created by Nataliia Romanyshyn and David Sousa & Priscila Doran, correspondingly.

4.1 ILS “The Adventures of the Droplet”

ILS “The adventures of the Droplet” (Subject Domains: Environmental Education, Geography, and Earth Science) is designed for students of 7-10 years old [24]. This delightful ILS introduces the concept of the water cycle in a funny and enjoyable way. Even the inquiry sequences of the cycle are presented in exciting and inspiring manner: Let's start!, Learn!, Play!, Summing up!, Let's discuss!, Rate it! (Fig.6).

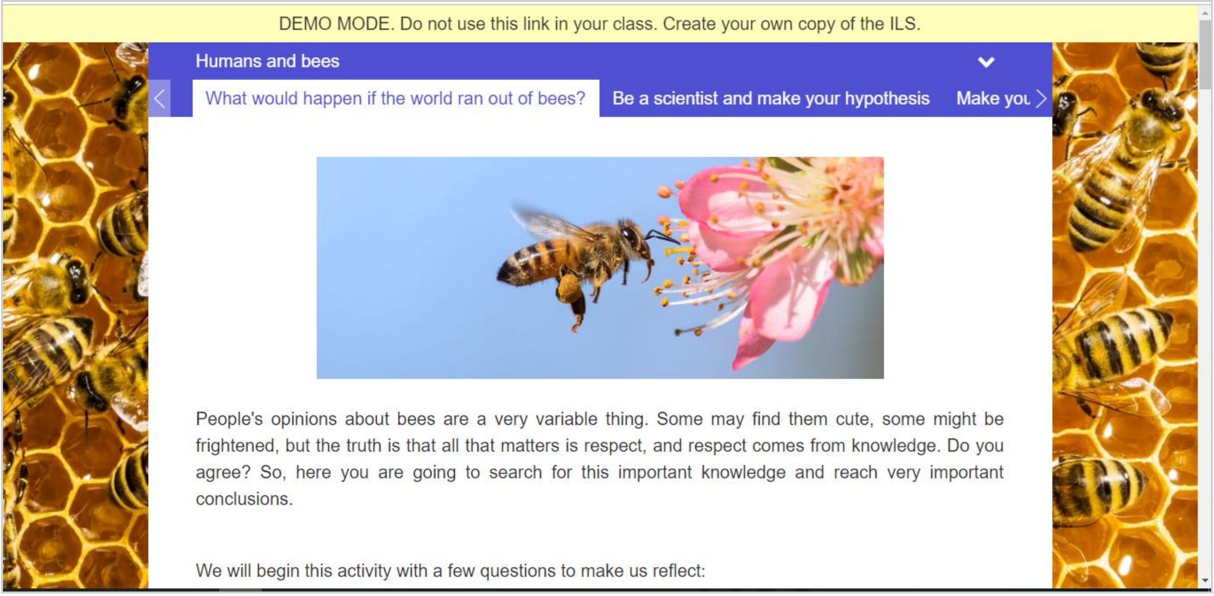
The ILS author is inviting a little kid to journey and asking to refresh the prior knowledge in the form of a short quiz. Then the student is asked to watch a video about a trip that a droplet has made. Since kids cannot focus for a long period at one subject matter, the video suggested to pupils is short, less than 1 min long. The reflecting tool allows for focusing students’ attention on the essential components of the topic. The experiment about the natural water cycle is given in a game setup. The Concept Map is used by the teacher to check student’s reflection on the travel of water around the world. The teacher asks student to share their observation and make a simple conclusion. A little fairy tale and set of questions finalize the ILS. Try this ILS to feel out the beauty of it!


РЕЖИМ ДЕМО. Не використовуйте це посилання у своєму класі. Створіть власну копію ILS.

Figure 6. “The adventures of the Droplet”, ILS Phase: Play!

4.2 ILS “Humans and Bees”

ILS “Humans and Bees” (Subject Domains: Biology, Chemistry, Environmental Education, Geography and Earth Science) is designed for students of 7-16 years old [25]. In this ILS student will reflect on the link between humans and bees, and research the possible human factors that affect bees in both positive and negative ways. Students will use an online simulator that allows for the variation of bee numbers, flower numbers and their influence on each other. Furthermore, students will learn about the scientific method and procedure that they have to have in mind when making a scientific research (Fig. 7).



DEMO MODE. Do not use this link in your class. Create your own copy of the ILS.

People's opinions about bees are a very variable thing. Some may find them cute, some might be frightened, but the truth is that all that matters is respect, and respect comes from knowledge. Do you agree? So, here you are going to search for this important knowledge and reach very important conclusions.

We will begin this activity with a few questions to make us reflect:

Figure 7. “Humans and Bees”, ILS Phase: What would happen if the world ran out of bees?

After the performed research, the students independently come to some conclusions, use tools to check if their hypotheses at the beginning of work with this learning space have been valid. It is very important to encourage students to work in groups or pairs, since they may take advantage of the knowledge gained from each other and develop 21st century skills of collaborative work and communication. To do this, use the Phase: Share with your class and discuss! – where the following task: “Now ... what do you think that humans could do to improve their behavior towards bees? Imagine that you were invited by the government to produce an awareness campaign to teach citizens about personal choices that could help to protect the bees. What would you create? What advice would you give? Work with your group to create something like this and upload you work below” is suggested. While students work on their own following the scaffold of ILS, the teacher has the opportunity to monitor the results of each student (the time and quality corresponding to the performance at the phases of learning) with the help of Learning Analytics apps - platform-specific evaluation tools [10].

Analyzing the published ILS, teachers indicate that it is crucial that the ILS contains an extremely diverse training material: online lab, problem questions, video clips, games, illustrations, reflection activity, guides, etc. From such massive collection it is easy to build the teaching materials for a large variety of learning styles.

5 CONCLUSIONS

The ILS is the space where an engaged, active, independent, and meaningful learning process in science curricula for all education sectors is incorporated. The ILS is the personalized learning environment for students where they can conduct scientific experiments, develop research skills, and gain new knowledge *by themselves*. Such approach helps students to build the responsibility in a smart, sustainable, and inclusive career development, to be responsive to the social challenges, and to be prepared for the life-long learning action. The ILS is the supportive tool for a development by students of innovative, creative, and digital skills. It also helps to manage different students’ learning styles. Moreover, the ILS is suitable for kids’ education at home or at hospitals. Thanks to contemporary communication instruments, various learning resources including inquiry-learning spaces and online experiments are available for students worldwide. This is a great solution to illuminate the challenges and meet the demands of growing globalization in education.

The organized visionary workshops show an impressive interest of primary school teachers of the Ivano-Frankivsk region in the Go-Lab ecosystem. This allows estimating that Go-Lab ecosystem will be in excessive demand by teachers of primary schools in Ukraine and in other East European countries. It demonstrates that the requirements of the online laboratories that match primary school curricula and age of the students need a close collaboration between developers of online laboratories, games and simulations, and representatives (teachers, trainers, lecturers, museum employees, and policy-makers) of primary education in formal, non-formal and in-formal settings. Besides this, organization of regional orientation workshops for teachers and school leaders will be beneficial to facilitate the Go-Lab ecosystem implementation in schools framework, especially in mountain and rural regions. During this motion, large number of teacher will become multipliers prepared for further distribution the IBSE approach in primary teaching instruction. In addition, different guided instructions such as “Creating ILS in 5-10 steps”, “Go-Lab ecosystem in MOOC”, etc. available in national languages and, as a result, eliminating the language barrier, will promote the use of the Go-Lab ecosystem even more broadly.

The first detached implementation of ILSs in the schools of the Ivano-Frankivsk region shows students’ inspiration and enthusiasm for such kind of learning exercise. Based on this success, the authors have decided to continue the research on the implementation of the IBSE in the ILS format in the regular curriculum to obtain quantitative data on the IBSE impact in the elementary school. The topic proposed for these studies is “I explore the world”. The further research results will be published in the journals and will be available on the project website. We believe that this paper will be useful for educators in formal, non-formal and in-formal settings of elementary education as well as for developers of the online laboratories for elementary school students.

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