Preliminary Go-Lab requirements specifications, needs analysis, and creative options

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Go-Lab

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Preliminary Go-Lab requirements specifications, needs analysis, and creative options

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Executive Summary

This deliverable D3.1 consists of two major parts: Part 1 reports on the design, implementation and findings of the Go-Lab Teacher and Student surveys that aimed to understand the current IT usage habit of the teachers and students as well as their experiences with online labs. Each of these two multilingual web-based surveys had more than 300 responses. Overall, the participating teachers and students had positive attitudes towards online labs. Nevertheless, efforts are needed to address the difficulties identified by the respondents, especially the availability and accessibility of online labs.

Part 2 covers two major types of participatory activity conducted in Go-Lab: Visionary Workshop (VW) and Participatory Design (PD) workshop. VWs aim to collect from a broad spectrum of stakeholders their future visions of using online labs in general and the Go-Lab Portal in particular for science education. PD workshops enable teachers and students with hands-on activities to share their feedback on the current design of the Go-Lab Portal. Methodologically, both VW and PD workshop are started off with an introduction to the vision and key concepts, especially the inquiry-learning cycle of Go-Lab. This basic understanding is crucial for the participants to discuss the related questions and provide feedback. A VW is followed by discussions to explore the future of science education, to develop scenarios of an online lab application and to identify key issues for the development of Go-Lab, and is ended with a survey. A PD workshop consists of a set of activities including mockups evaluation (computer-based using myBalsamiq and paper-based using the Layered Elaboration technique), selecting design options, focus groups and writing postcards.

Altogether **25 VWs** and **9 PD workshops** have been conducted in nine and five European countries, respectively, from May to August 2013. They involved in total **728 participants**, consisting of **685 teachers** and **43 students** from secondary and primary schools. Comprehensive empirical data have been gathered and analysed. Results thereof enable us to answer a set of pedagogical research questions (RQs) and to derive a list of requirements; both types of input are highly relevant to the design of the Go-Lab Portal. Specifically, the requirements are prioritised in terms of obligation, namely "must have", "should have" and "nice to have". They are also categorised with regard to their implications: general pedagogical requirements, general technical requirements, design of the existing mockups, and creation of new tools for the use of online labs. These empirical findings can inform the future work of the pedagogical team (WP1) and technical team of Go-Lab (WP4/WP5).

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1   Introduction

The main objective of *participatory activities* in the Go-Lab project is to identify, update and integrate, on an ongoing basis, requirements for developing the Go-Lab Portal to ensure that it will be highly useful, usable, desirable and pleasurable. The participatory activities are to be carried out as a series of events in which different stakeholders (including teachers, students, lab owners, researchers, and developers) are actively involved to discuss and generate insights into the ongoing pedagogical and technical work of Go-Lab, thereby contributing to the development of the Go-Lab community (WP6, WP7) and of lightweight user interfaces of the Go-Lab Portal (WP4, WP5).

There are two major types of participatory activities: Visionary Workshop (VW) and Participatory Design (PD) workshop, which are implemented under the coordination of WP6 and WP3, respectively. VW aims to collect from a broad spectrum of stakeholders their future visions of using online labs in general and the Go-Lab Portal in particular for science education. PD workshop enables teachers and students with hands-on activities to share their feedback on the current design of the Go-Lab Portal (Task *3.2* and Task *3.3*).

Furthermore, prior to the implementation of the Go-Lab Portal, it is deemed necessary to understand the IT usage of two major user groups of Go-Lab – teachers and students – in general, and their experiences with online labs in particular (Task *3.1*). To meet this goal, we have designed and conducted two web-based surveys: one is focused on teachers and the other on students.

Go-Lab aims to implement the project's goals at a large scale in Europe. Ten countries, including Austria, Belgium, Cyprus, Estonia, Germany, Greece, the Netherlands, Portugal, Spain and the UK, have been selected for the first phase of the project. Stakeholders from these countries are involved in the surveys, VWs and PD workshops. Results thereof are presented and discussed subsequently.

2   Baseline Data: Teacher and Student Surveys

Two web-based surveys known as "Sharing Practical Experiences about Online Labs" (http://www.go-lab-project.eu/go-lab-surveys) have been designed and launched since end-January 2013. The original English version has been translated into Dutch, Estonian, French, German, Greek, Portuguese and Spanish by the respective Go-Lab partners, to facilitate the participation of the largest possible communities across Europe. The main target groups are primary and secondary school teachers and students aged 10 to 18 years old.

2.1 Survey Design and Implementation

The surveys consist of several parts: Demographic data, IT infrastructure, Tools for learning, and Experience with an online lab. It takes on average 20 and 30 minutes to complete maximum 22 questions and 50 questions[1] in the student and teacher survey, respectively. From end-January to end-August 2013, responses from 334 students and 313 teachers have been collected. As the surveys aim to capture data to address different needs of WP1, WP3 and WP5, they become inevitably long and some questions are thus made optional. Also, not all the teachers and students invited to take part in the surveys have had experience of using online labs. These factors explain the full and partial completion rates of the two surveys (Table 1).

Country	Teacher			Student		
	No. of full responses	No. of Partial responses	No. of responses received	No. of full responses	No. of Partial responses	No. of responses received
Austria	1	2	3	0	1	1
Belgium	5	6	11	12	0	12
Bulgaria	1	0	1	0	0	0
Croatia	0	2	2	0	0	0
Cyprus	29	15	44	18	2	20
Estonia	33	16	49	47	12	59
Finland	0	1	1	0	0	0
Germany	1	1	2	0	2	2
Greece	13	16	29	13	3	16
Ireland (Rep)	0	3	3	0	0	0
Italy	6	2	8	29	20	49
Netherlands	1	19	20	2	2	4
Norway	0	1	1	0	0	0
Poland	4	2	6	46	6	52
Portugal	24	25	49	23	12	35
Romania	1	0	1	0	0	0
Spain	25	18	43	55	22	77
Sweden	0	1	1	0	0	0
Switzerland	0	1	1	0	0	0
U.K.	9	16	25	3	0	3
Others*	5	7	12	0	0	0
Total	**158**	**154**	**312**	**248**	**82**	**330**

*Europe-neighboring countries and beyond: China, India, Israel, Malaysia, Singapore, and US

Table 1. The response rate and completion rate of the Teacher and Student Surveys

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[1] As there are conditional questions in both surveys, the number of questions answered can vary with individual respondents.

Nonetheless, the uneven distribution of responses over the European countries can be explained by the fact that the surveys have been administered by the Go-Lab team to their networks who are more likely to have some experience with online labs (e.g., EUN has contact with schools in Italy and Poland, although there is no Go-Lab partner in these countries). Apparently, this approach resulted in a sampling bias, skewing towards a higher prevalence of the online labs usage than it would have been with entirely random samples. Given the difficulty of involving the broader European school populations in this survey study, the representativeness of the current sample and the validity of the results could be compromised.

2.2 Results and Discussion

2.2.1 Student Survey

2.2.1.1 Demographic data

The majority of the respondents were secondary school students (n=206, 62.4%), followed by university undergraduates (n=101, 30.6%) and primary school students (n=23, 7%) (Figure 1). The gender distribution was almost equal: male (51%) vs. female (49%). The respondents originated from 15 European countries with most of them coming from Spain (23%), followed by Estonia (18%), Poland (16%), Italy (15%), and Portugal (11%) (cf. Table 1).
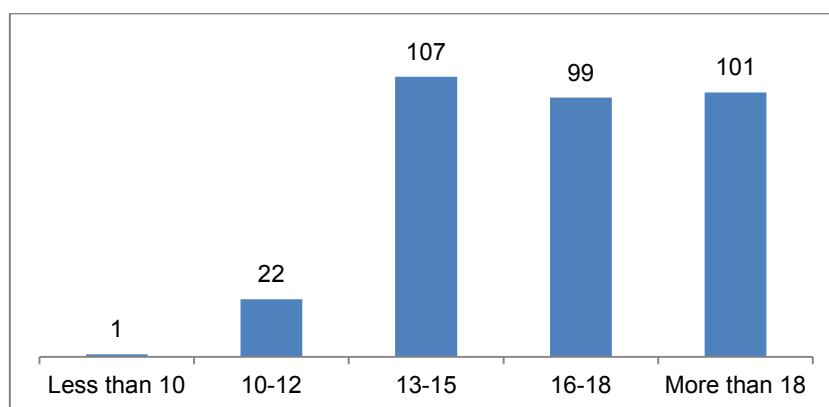
Figure 1. Age distribution of student survey

2.2.1.2 IT Infrastructure

The survey results show that a typical student user of the Go-Lab portal would use a desktop or laptop computer running Microsoft Windows operating system and Chrome web browser. Interestingly, only 17% of the student respondents had mobile phones as their primary IT device whereas tablets were much less popular (4%). Chrome was the most popular web browser for the students (60%), followed by Firefox (21%), Internet Explorer (12%), and a small percentage for Safari and Opera (Figure 2).
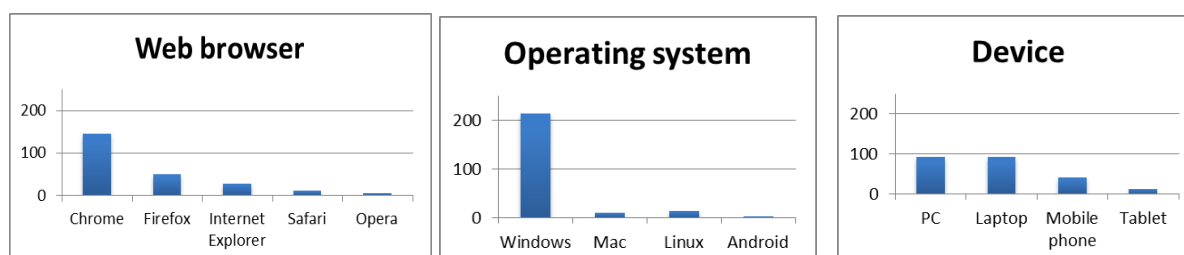
Figure 2. **The use of web browsers, operating systems and IT devices by students.**

2.2.1.3 Tools for learning

The students' responses indicate the frequency of the use of different software tools to support their learning. The frequency was divided into five ranges: never, infrequent (less than 2 hours per week), moderate (between 2 and 5 hours per week), frequent (between 5 and 10 hours per week) and very frequent (more than 10 hours per week). The tools were organized in five categories: search engines (e.g., Google, Bing), email (e.g., Gmail, Yahoo), social media (e.g., Wikipedia, blog, Facebook, YouTube), Microsoft Office software (e.g., Power point, Word, Excel) and Educational software (e.g., games, computer-aided design). As shown in Figure 3, the students used search engine and social media the most, followed by the moderate use of Microsoft Office and email. The least common use, however, was educational software. Other tools repeatedly referred to by the students, which may include online labs, were Virtual Labs, Stagecast Creator, Eclipse, Inspiration Software (Kidspiration), Google translate, Wireshark, Khan Academy, PhET simulations and Matlab.
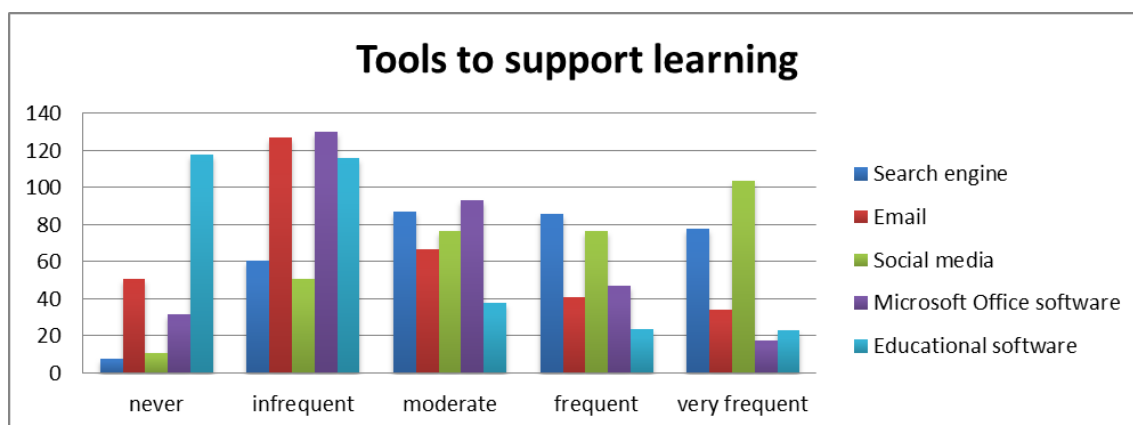
Figure 3. **The frequency of the use of software tools supporting students learning**

2.2.1.4 Experience with online labs

The Student Survey was aimed to be distributed to respondents with the experience of using online labs. However, only 296 out of the total 330 respondents reported that they had so: 43% have used virtual labs, 38% remote labs, and 19% both. The level of experience with the online labs tended to be low (Figure 4). The students were asked to name online labs they had used. The most cited online lab was WebLab-Deusto and PhET Simulations, followed by some country-specific laboratories such as Loodusteaduslikud mudelid põhikoolis and MIKSIKE in Estonia or HYPATIA in Greece and Cyprus. Some oft cited examples included Stagecast Creator, Inspiration Software (Kidspiration) and Faulkes Telescope Project.
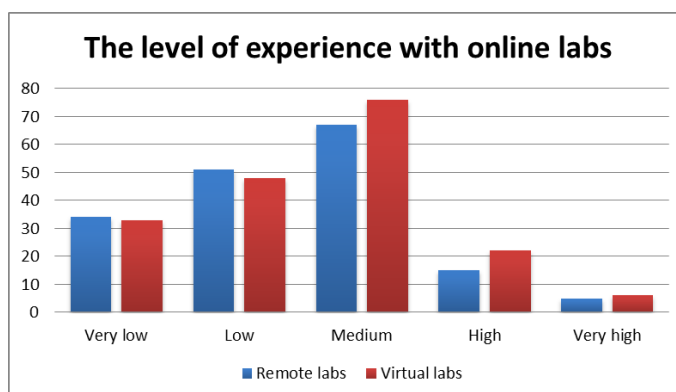
Figure 4. **The students' level of experience with the online labs which they had worked with**

90% of the students have learned from their teachers about online labs, which were predominantly in the domain of physics (60%), including elementary particles, electricity, electronics and astronomy. The proportion of the online labs for chemistry, mathematics and biology was rather low (13%, 7% and 2%, respectively) and the other labs were categorized as general science. According to the students' estimation, 74% of the labs were designed for the age groups above 13 years old (i.e., secondary school or higher); the largest proportion of the labs were estimated to be for the age group "more than 18 year old" (Figure 5).

Figure 5. **Distribution of age-groups for online labs as estimated by the students.**

The usage of online labs shows a notable difference in the number of lessons with an online lab between the school children and the university undergraduates. On average, approximately two lessons lasting 38 minutes and occupying 40% of the lesson time were for the former and eleven lessons lasting 94 minutes and occupying 58% of the lesson time were for the latter (Table 2).

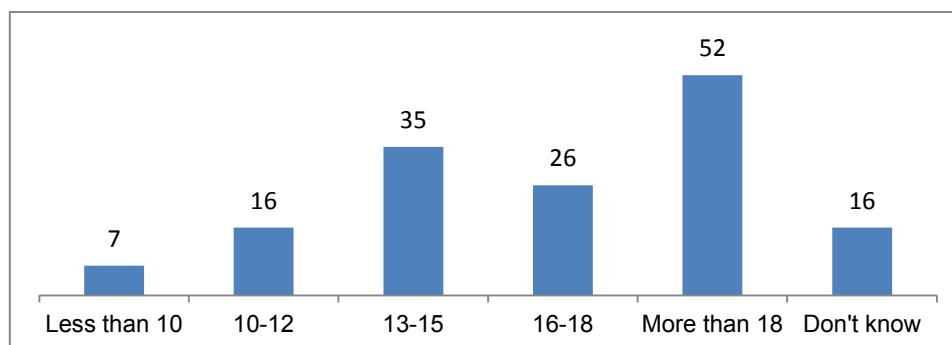| N = 264	Number of lessons		Minutes per lesson		% of lesson for online labs	
	School students	University undergraduate	School students	University undergraduate	School students	University undergraduate
Average	2.13	11.82	38.1	94.39	40.53	58.16
Std. Dev.	1.43	16.01	20.47	129.38	30.48	26.13
Median	2	3	40	60	32	55

Table 2. **Number of lessons, duration and percentage of a lesson using online labs as reported by students**

About 50% of the students experienced an online lab during practical exercises carried out in the classroom whereas about 30% were only shown as a demonstration without any interaction. The remaining 20% had the possibility to use the lab at home or in other ways (e.g., extracurricular project). The majority (~90%) used the online labs on an individual basis, which were complemented by some group work implemented either online or co-located or both.

The students were asked to report the source and type of help for deploying the online labs. The most frequent request for support was the instructions on using the lab. The common difficulties with the online labs were experiment setup, measurements and the language barrier of the English interface for non-native speakers. Other difficulties included the access procedure (e.g., login) and lab instructions (e.g., commands use), required theoretical knowledge required, and interpretation of results. The mostly sought help, not surprisingly, was teachers (76%) (n=212), followed by peers (15%), help text of the online labs (7%), and others (2%) (e.g., Google).

The students were asked to evaluate the online lab they had experience (Section 2.2.1.4) with nine given statements on the ease of use, usefulness, and intention to use (Figure 6) (cf. Technology Acceptance Model [TAM], Davis, 1989). In summary, most of the students found the lab with which they familiar easy to use, useful and motivating, but they were not entirely convinced that the

online lab was more effective than a real lab. The overall user experience with the existing online labs was positive (N = 249, *M*= 3.44 out of a 5-point Likert scale, 1: very negative, 5: very positive).
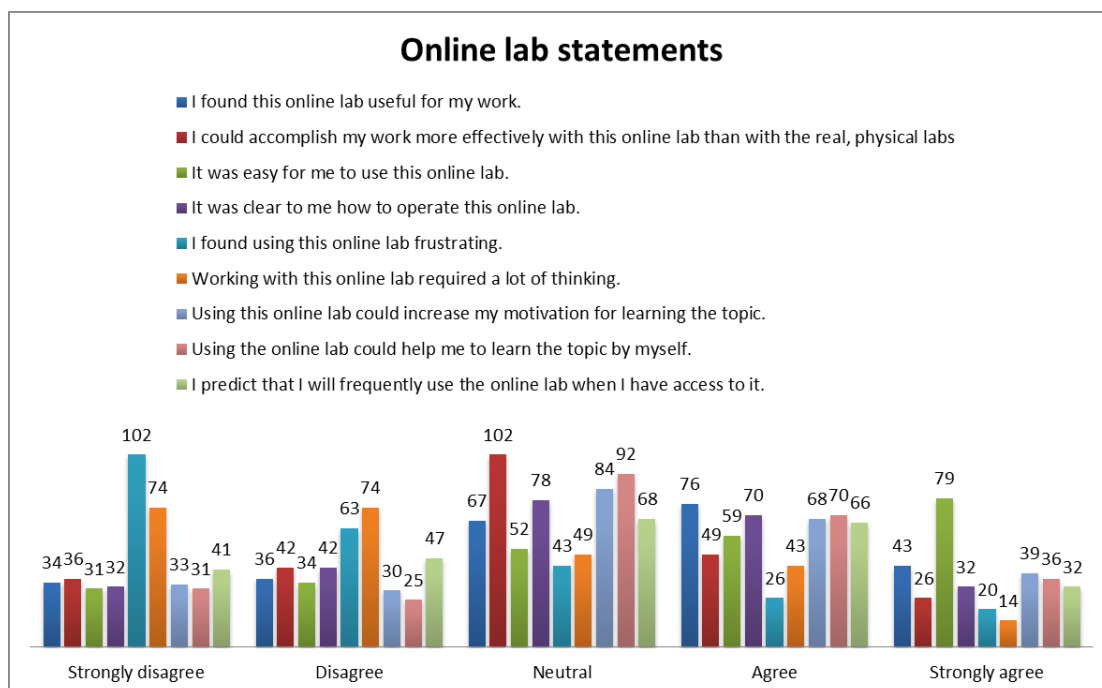
Figure 6. **Evaluative statements of the online lab identified by the students**

There were many desirable features of online labs described by the students with the most desirable one being ease of use. The students also enjoyed the choice of experiments or objects in a lab, the possiblity to work remotely and from home, and the lab characteristics such as clarity, efficiency, usefulness, and simplicity among others. In contrast, the students identified several undesirable features as well. The non-native speakers would prefer having online labs localized in their language (e.g., Polish, Spanish) and many students referred to the experimental device failures in the remotely controlled physical equipment and simulations. Pre-requisite knowledge, unclear instructions, slow and complicated interface or limited time to perform an experiment were among the negative effects experienced by the students. The online lab content translation and the use of tutorials (video, examples, FAQ) were the most cited solutions to these problems. Moreover the students suggested making online labs more visually appealing, reliable, better performing and user friendly. They can be also enhanced by brainstorming and game activities and by an important feature of saving form information to avoid the need of re-entering text.

The majority of the students were positive about the use of online labs. About 60% (N=258) of the students responded "Yes" to the question whether they would recommend the use of an online lab to their peers (cf. 15% "no"; 25% "don't know"), because it is enjoyable, interesting, useful, creative, helps to learn the topic, and provides access to new experiments.

2.2.2 Teacher Survey

2.2.2.1 Demographic Data

About 61% (N=312) of the respondents to the Teacher Survey were secondary school teachers. This group was followed by smaller clusters of primary school teachers (15%), university teaching staff (9%), researchers (5%), and science teacher trainees (2%), and others (8%). Most of them teach physics (Figure 7). The average teaching experience was 13.8 years (N=275, SD=10.9).
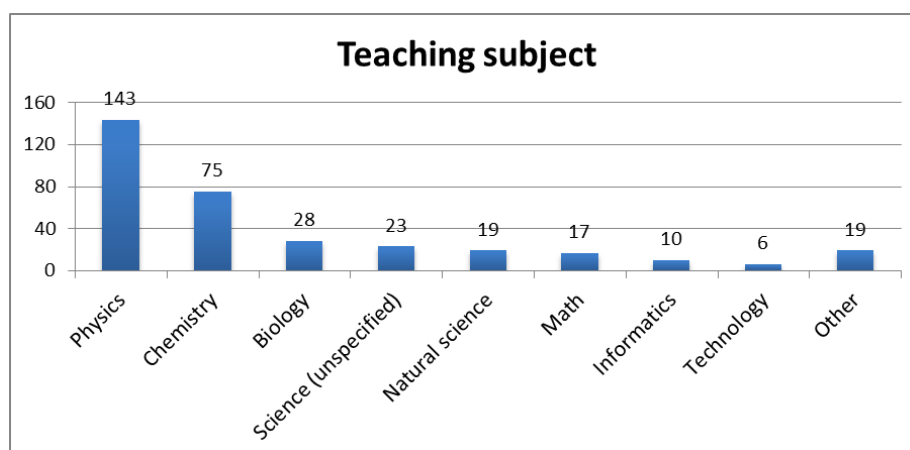
Figure 7. **Distribution of the main teaching subjects**
(Note: some teachers indicate that they teach more than one subject)

The gender distribution of the respondents was even: 51% female and 49% male. The largest age group was 36-45 (Figure 8). Most of them resided in Europe and a smaller number in non-European countries (Table 1).
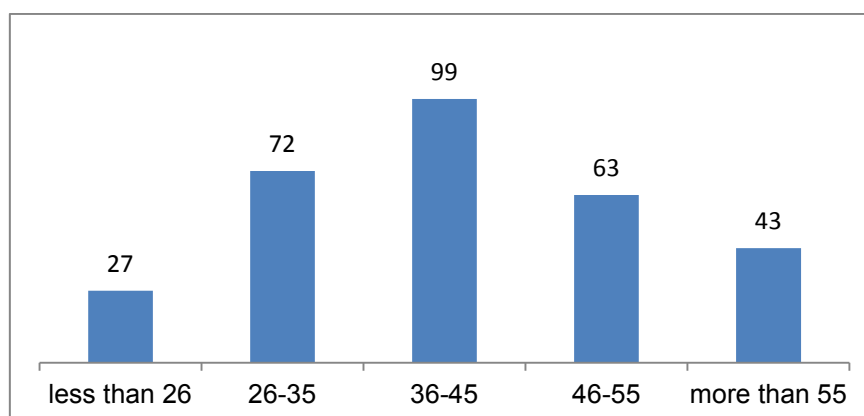
Figure 8. **Age distribution of teacher respondents**

2.2.2.2 IT Infrastructure

The survey data suggests that typically a teacher uses a laptop running the Microsoft Windows operating system with the Chrome web browser (Figure 9).
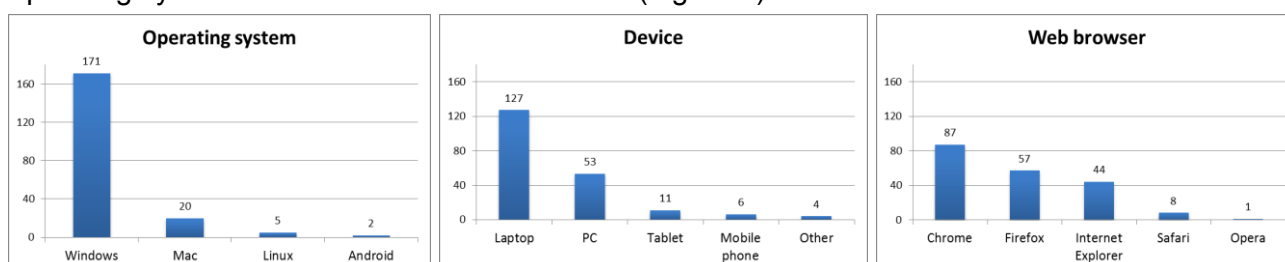
Figure 9. The uses of different operating systems, IT devices and web browsers by the teacher respondents

2.2.2.3 Tools for teaching

The teachers' data report on the frequency of the use of software tools supporting teaching including Course management systems (e.g., Moodle, Blackboard), Social networking platforms (e.g., Twitter, Facebook), Web search/research (e.g., Wikipedia, Google search), Educational tools (e.g., Khan Academy, iTunesU), Video tools for sharing (e.g., YouTube, TED Talks) and File synchronization / cloud storage (e.g., Dropbox, Windows Skydrive). The frequency was divided into

five ranges: never, infrequent (less than 2 hours per week), moderate (between 2 and 5 hours per week), frequent (between 5 and 10 hours per week) and very frequent (more than 10 hours per week). Almost every teacher reported using a web search, which remains the most common tool to support teaching. Video tools, although not the most frequent, were often used by the teachers. Social networking software seemed not as popular for the teachers as it was for the students (Section 2.2.1.3). Interestingly, the educational tools were used only occasionally by the teachers (Figure 10).
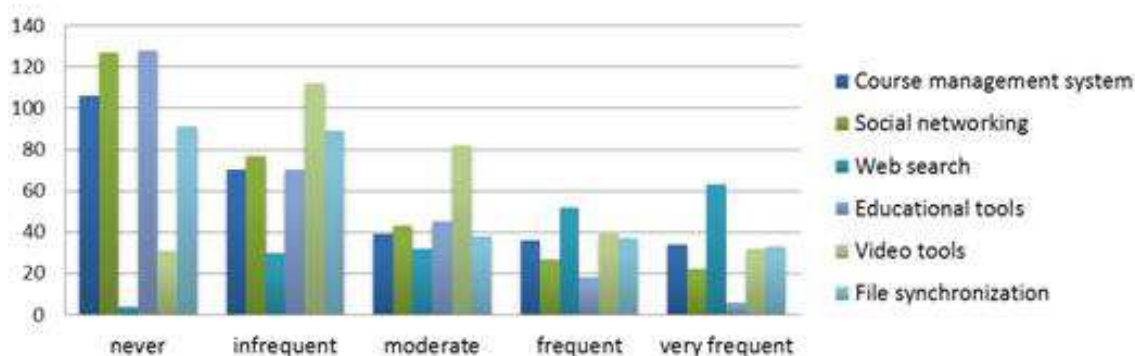
Figure 10. **The usage of teaching support tools of the teacher respondents.**

2.2.2.4   Experience with online labs

Of the 268 teacher respondents who reported having experience with online labs, 54% had it with only virtual labs, 20% only remote labs and 26% had both. The level of experience with the different types of the online labs tended to be medium (Figure 11).
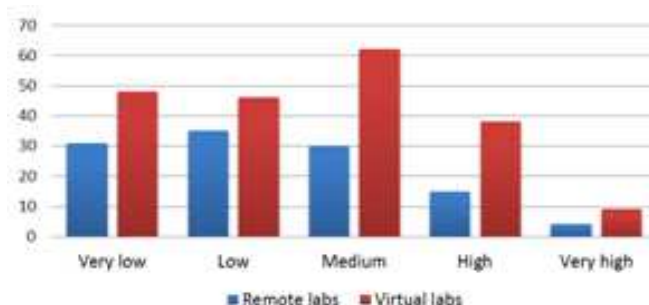
Figure 11. **Reported level of experience with online labs**

In addition to the list of the online labs given by the students (Section 2.2.1.4), the teachers provided some others (Appendix A). The online labs identified were reported to be used primarily in the domain of physics and astronomy, followed by chemistry and biology. Only a few labs were used in other domains such as electronics, mathematics, informatics and geography. Also, the teachers' responses corroborated the students' opinion (Section 2.2.1.4) that most of the online labs (74%) were designed for the age group of 13-18 years old.

The teachers have learned about the online labs from several sources: formal recommendations by an educational authority (e.g., part of a syllabus, an expert in a training course), web-based research on their own, informal recommendations by peers, and publications (e.g., science book, academic journal, magazine, newspaper). In addition, they have identified other sources of new knowledge about online labs, including training activities (e.g., CERN, NUCLIO), European projects (e.g., European Schoolnet), conferences, workshops, university courses, and even their own students. The perceived difficulty of finding such labs was considered low.

The frequency of using online labs as reported by the teachers shows large variations (Table 3). On average a teacher used an online lab in approximately 19 lessons lasting 47 minutes and occupying about half of the lesson time.

	Number of lessons (N=175)	Minutes per lesson (N=157)	Percentage of lesson (N=95)
Average	18.8	46.9	49.3
Std.dev.	80.2	46.3	30.0
Median	5	45	50

Table 3. The usage of online labs in lessons as reported by the teachers

78 teachers (out of the 174 responses) reported that they used the online labs for practical exercises to be carried out by the students in the class, while 41 used them as a demonstration tool that is not interactive for the students. Only 19 teachers used the online labs for homework assignments. Some reported using a combination of some or all of the aforementioned options. Furthermore, personal uses of online labs for training and self-study were identified. According to the teachers, the students' interactions with the online lab were mostly implemented as practical exercises in a group (co-located).

While most teachers expressed that they did not need help in using online labs, when needed, looking up an instruction manual/online help text appeared to be a popular approach; the other options were asking a colleague and consulting (or receiving training from) the creator of the online lab (Figure 12). The amount of help needed by the students was estimated by the teachers to be rather low (for the scale of 0-100, M=38, SD=29). In case help was needed, the teachers supported their students with the lab access, text translation, theory understanding, lab navigation, experiment setup, tools demonstration, and results interpretation. These issues also correspond well to the lab features that were found difficult by the teachers.
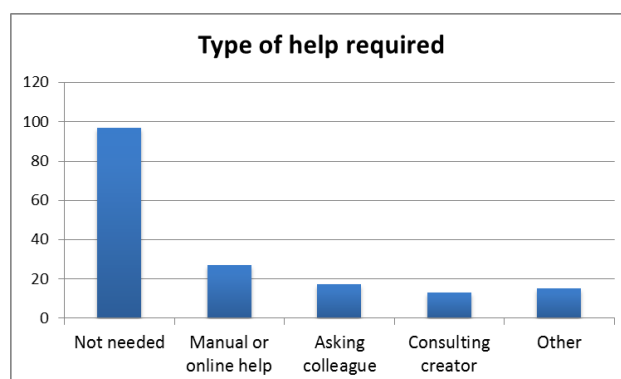
Figure 12. Help for using online labs the teachers sought

The teachers were asked to indicate the extent to which they monitored the progress of their students when using an online lab with a scale of 0 (not at all) to 100 (all the time), and the relative importance of such monitoring to them again with a scale of 0 (not important at all) to 100 (very important). The respective results are M=50.0, SD=31.9 and M=65.2, SD=30.8, respectively, suggesting that the teachers may see the value of monitoring but, for some reason, choose not to implement it to a full scale.

The teachers were asked to evaluate the online lab they had experience with nine given statements on the ease of use, usefulness, and intention to use (Figure 13). In summary most of the teachers found the labs useful, easy to use, clear and motivating, and the perceived frustration level was low. The overall user experience was positive (Figure 14).

The most desirable features of the online labs contributing to the positive user experience included collaborative work, access to a telescope, better and faster observations/results than with real materials, exact representation of real experiment, and ease of use. The teachers also listed some

undesirable features including limited availability for booking, language constraints, technical problems, and not exact representation of the real system.
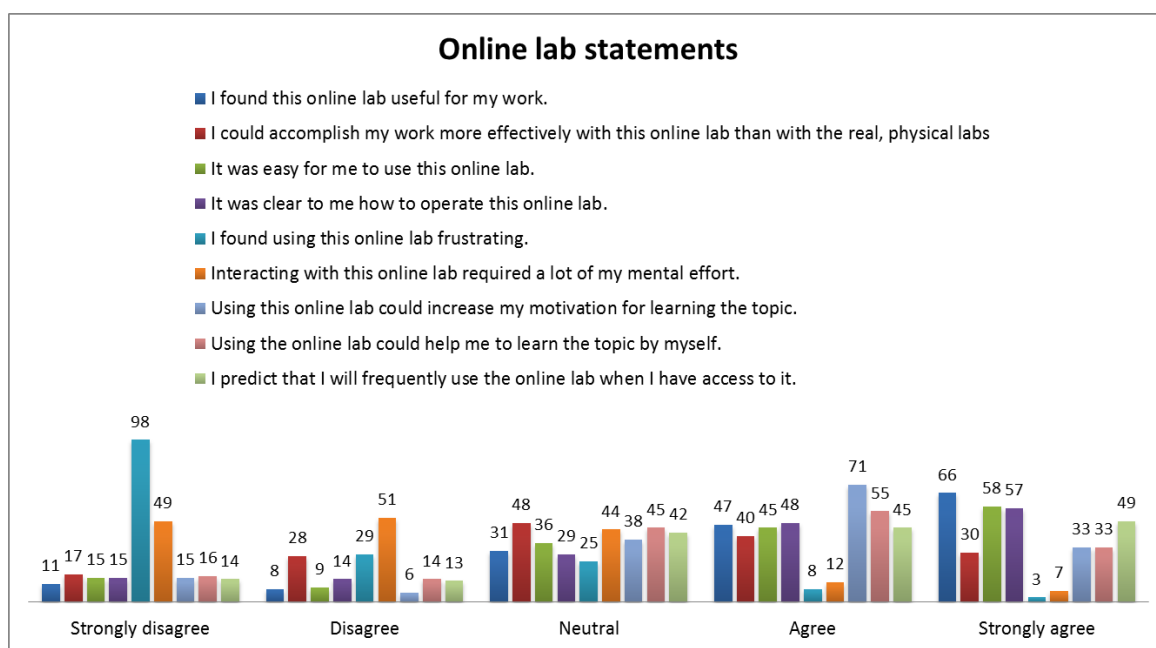
Figure 13. Teachers' rating on the acceptance of the online labs which they had experience
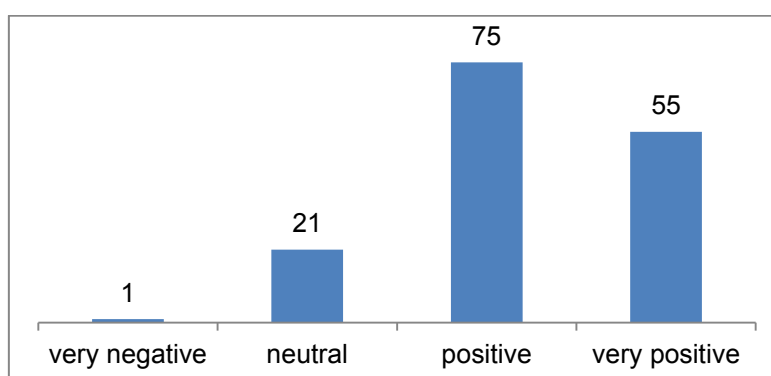
Figure 14. Teachers' ratings of user experience with the online labs which they had experience.

Most of the teachers were positive about the use of online labs. About 90% (141 out of 157 responses) of them chose "Yes" to the question whether they would recommend the use of an online lab to their peers (cf. 2 chose "no"; 14 chose "don't know").

2.2.2.5 *Inquiry-based learning knowledge*

The teachers were asked to indicate their own level of knowledge of the inquiry-based learning method with a scale of 0 (not at all) to 100 (very high), and the results show that on average they had a medium level (N=181, *M*=52.1, *SD*=29.6). Further investigation of the teachers' experiences with inquiry-based learning focused on *scaffolds* (or learning tools; D1.1) provided by the online labs that the teachers have used (Figure 15). Results showed that the experiences tended to be positive. Particularly favourable to the teachers were the scaffolds for Data collection and Observation.
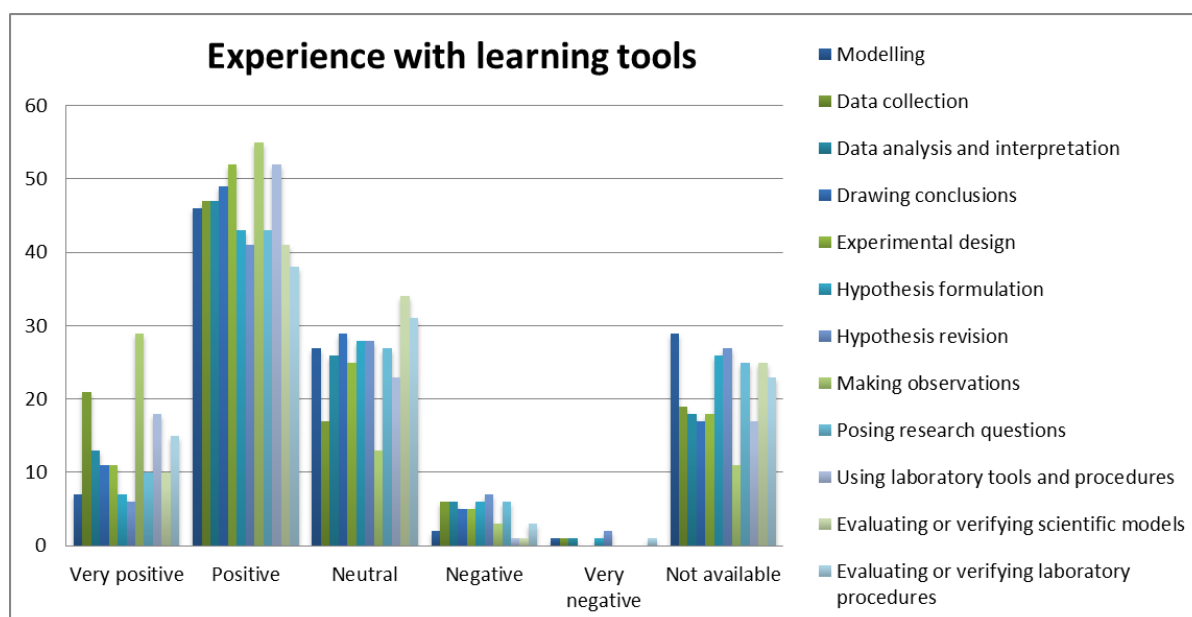
Figure 15. Teachers' evaluation of different types of scaffold provided by online labs

As a follow-up question, the teachers were asked to evaluate the necessity of such scaffolds. Two prominent ones in the "must have" category are "Making observations" and "Using lab tools and procedures" (Figure 16). This question was answered by a batch of 110 teacher respondents.
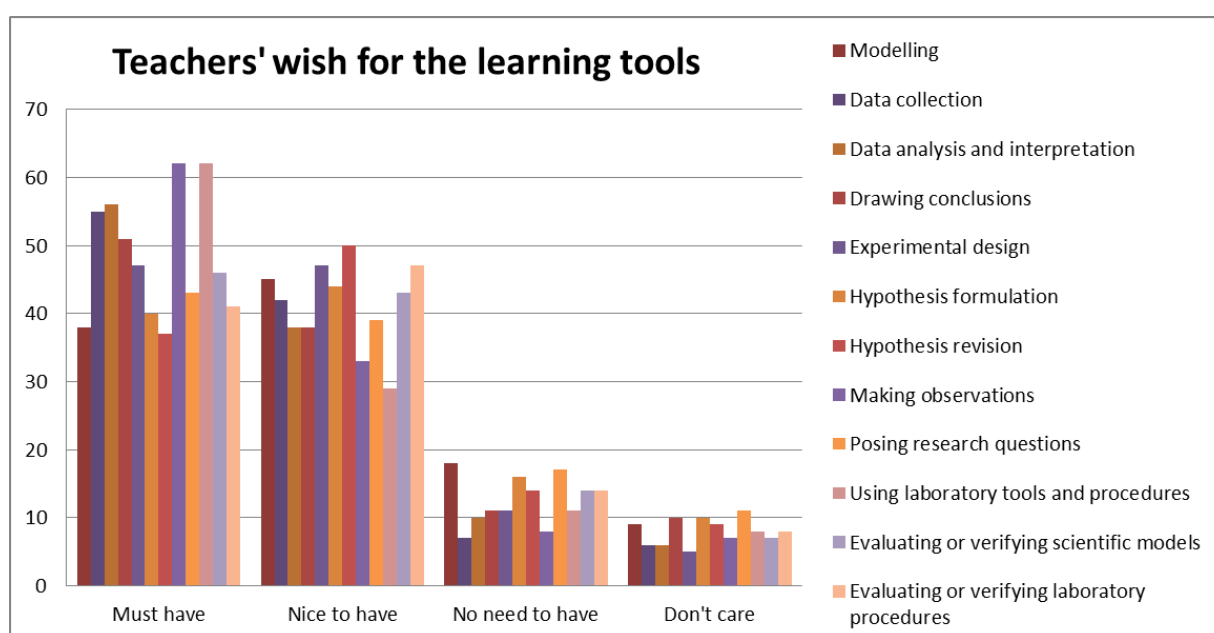
Figure 16. Teachers' wish lists for scaffolds (N =110)

The second batch of the teacher respondents (N=70) was presented a modified question on the necessity of scaffolds. Instead of 12 types of scaffold as shown in Figure 15, the Go-Lab five-phase inquiry-based learning cycle was presented. The teachers were asked to indicate the necessity of scaffolds for each of the five phases, namely, Orientation, Conceptualization, Investigation, Conclusion, and Discussion, and to provide examples. Results show that scaffolds would likely be needed in all the phases (Figure 17).

Although some teachers pointed out that they were not so familiar with the terms for the five phases, they provided several suggestions for scaffolds. For instance, using games in the

Orientation phase can capture students' attention. The scaffolds in the conceptualization phase should help students decide which research question is scientific or achievable, because there can be an infinite number of the research questions. Some tools should be able to assess students' premises in order to prevent them from pursuing an invalid assumption or to enable students to ask questions to verify their assumptions. The tools in the Investigation phase should be readily available to guide students in unexpected situations, and can help students better organize the investigation procedure (e.g., tables or graphs). Some teachers indicated interest in the monitoring tools to follow students' progress and see if all necessary phases are completed. While students should be the primary source of results in the Conclusion phase, a tool that could help students record and formulate their findings when needed should be available. Finally, the teachers thought that the Discussion phase is very important, yet the most challenging phase for the students and it should be managed or monitored. For example, students are allowed to discuss using a chat function, but it would be switched on/off by the teacher. Another proposed tool is that it can make the students reflect on their own opinions.
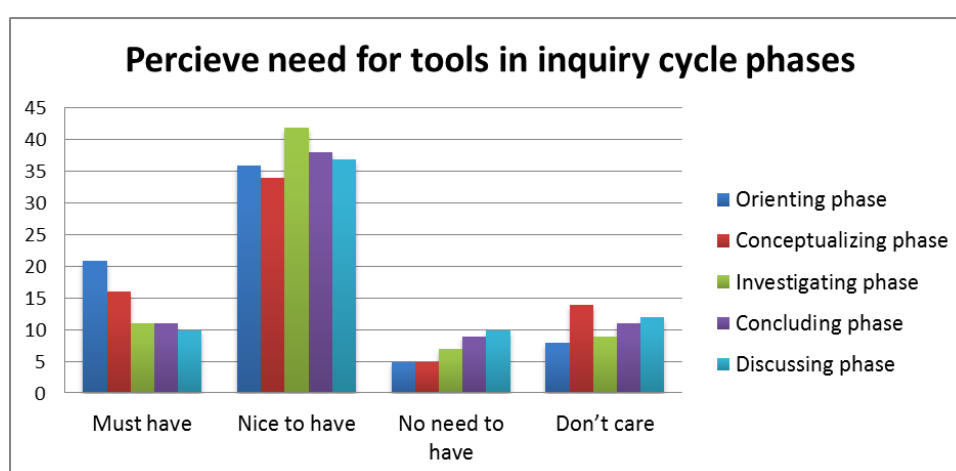
Figure 17. Teachers' evaluation of the necessity of scaffolds in each of the five inquiry cycle phases.

2.3 Conclusion on Student and Teacher Surveys

The two surveys, despite their limitations, provided a more up-to-date picture of the usage of online labs in some European countries. Results indicate that both the participating teachers and students had positive attitudes towards online labs, appreciating their potential educational values. Nonetheless, the prevalence of online labs appeared to be lower than expected, given the fact that about one-third of the teachers and students who visited the survey could not respond to the questions on online labs because of their lack of exposure to any of such labs (Note: These respondents completed the other parts of the survey, which provided us some useful information about their IT usage).

In reflecting on this task, we have encountered some typical challenges in designing and implementing web-based surveys. For instance, addressing different research questions has inevitably led to a relatively long questionnaire, which would compromise the response rate. A caveat is that we are well aware of the other existing surveys (e.g., "*Survey of Schools: ICT in Education, Benchmarking Access and Use and Attitudes to Technology in Europe's Schools*", Feb 2013, EUN), which have been investigated in our internal deliverable (G3.1, M6). Results of the previous and current Go-Lab surveys could support the technical and pedagogical teams to make informed decisions of their respective work. For instance, knowing which IT devices are commonly used by teachers and students would influence the technical team's decision on the main display

resolution of the Go-Lab Portal. Similarly, understanding which scaffolds are valued by teachers can help the pedagogical team design learning scenarios for the effective use of the Portal.

3   Data Collection: Planning and Organizing Participatory Activities

3.1 Visionary Workshops (VWs)

3.1.1 Brief Description of VW – Goals and Objectives

The main purposes of VWs are to collect different stakeholders' views on the future of science education where online labs can play a significant role, and to build a community to sustain communication and collaboration. The views so shared can address the pedagogical, organisational and technological aspects of Go-Lab and can also be used for its future development.

3.1.2 Methodology and Organization of Visionary Workshops

There were two major types of VW, face-to-face and online, which had a similar structure and organization (details see D6.1). They are briefly described as follows:

3.1.2.1 Face-to-face VWs

A half-day face-to-face VW consists of three main sessions. In the first introductory session, participants are provided with the information about the Go-Lab project and an example of the "best practice" in the application of online labs, and then they are asked to explore the future vision of science education through brainstorming and open discussion. In the second session, participants can develop an online lab use scenario by working on a lesson plan for one of the suggested labs. In the final session, a plenary discussion is carried out to identify key issues for Go-Lab's future development; after that participants are asked to complete a survey to describe their experience with online labs and their future vision of successful implementation of Go-Lab online labs at their own institution.

3.1.2.2 Online VWs

An alternative format of VW is to carry out the participatory activities online. The workshop consists of two parts. The first part focuses on the presentation of the Go-Lab project, its aims and main benefits for teachers, students and laboratory owners. Some online labs included in Go-Lab are also presented to teachers. The second part is focused on the Go-Lab key concepts where teachers can navigate a Go-Lab mockup and discuss it with researchers. Teachers can go through the mockup step by step and get familiar with it, thereby enabling them to anticipate its future use. During their tour through the mockup, teachers are asked to comment on it, especially the functional and usability aspects.

3.1.3 Overview of Data Collection in VWs

A reporting scheme for VW is specified in G7.1. Accordingly, a partner involved in a VW is required to complete a report template and upload it to a repository. The report documents basic information about the VW, including date, location, number of participants, target group and type of activity along with a description of the implementation activities, online labs used/demonstrated and learning outcomes reached or expected. If a discussion or survey is part of the workshop, a summary of the responses is to be included in the report. Besides, any material in printed or electronic format that is related to the implementation activity is to be attached to the report (e.g., dissemination material handed to participants, educational material produced specifically for the activity, photos or videos taken during the event, etc.).

3.2 Participatory Design (PD) Workshops

3.2.1 Brief Description of PD Workshops – Goals and Objectives

PD workshops aim to capture requirements and practical feedback on the initial design concepts of Go-Lab in order: (i) to provide the pedagogical and technical team with empirical evidence on how to enhance the design and development of the Go-Lab Portal; (ii) to engage teachers and students in co-designing the Go-Lab Portal based on their needs and personal experiences, enabling them to have some direct influence on it and thus promoting their sense of ownership and community. PD participants can contribute their strengths to clarify design problems and to explore design solutions; they are encouraged to use their experience, knowledge, and creativity to work collaboratively with researchers and designers on some practical solutions.

3.2.2 Methodology and organization of PD workshops

The methodology of PD workshops is to: (i) achieve the aforementioned basic PD goals (Section 3.2.1); (ii) address the research questions in relation to the pedagogical frameworks for the Go-Lab learning spaces (Section 3.3); (iii) address the research questions pertaining to the relative effectiveness of paper-based and computer based evaluation methods (NB: the results thereof are not included in this document.)

There is a range of PD methods using different techniques, tools and materials (for an overview see Walsh et al. 2013). Activities that are relevant to the number and nature of participants, time and technological facilities available for the workshops have been selected and described in WP3 Participatory Activity Protocol (internal deliverable). Table 4 summarizes the selected methods consisting of five Activity Types (A – E).

Duration* Activity Type**	Short (2 hours)	Medium (3.5 hours)	Long (5 hours)
A) Starter	"Meet the Neighbour" (5 min)	"Personal Cards" (short card, 15 min)	"Personal Cards" (full card, 30 min)
B) Presentation	Go-Lab project (20 min)	- Go-Lab project (20 min) - Basic Concepts (10 min)	- Go-Lab project (20 min) - Basic Concepts (10 min) - Mockups (10 min)
C) Prototype evaluation	Balsamiq online mockup/Layered elaboration method with printouts (60 min)	Balsamiq online mockup/ Layered elaboration method with printouts (60 min)	Balsamiq online mockup/ Layered elaboration method with printouts (90 min)
D) Group Discussion	Selecting Design Option with a subset (30 min)	Selecting Design Option with the full set (45 min)	Selecting Design Option and Focus Group (90 min)
E) Summary	Postcard (5 min)	- Postcard (5 min) - Plenary (5 min)	- Postcard (5 min) - Plenary (5 min)

Table 4. PD session activities, duration and participants

Note: *The suggested duration is a rough guideline, which needs to be adapted to the situation, for instance, the length of a school lesson, and also to the type of participant. ** Not all five Activity Types have to be carried out. For instance, in using an intact group, A) Starter can be skipped

3.2.2.1 Starter

The methods under the Starter include two introductory activities "Meet the Neighbour" and "Personal Cards" that are selected based on the PD workshops length. During this PD activity the participants meet each other and create a shared view on the inquiry-based learning approach or share their teaching experience.

3.2.2.2 Presentation

The main rationale underlying the presentation is to get the participants familiarize with the critical aspects of the Go-Lab project (Table 5).

	Basic description	**Time**
Go-Lab project	In this introductory presentation participants get briefly acquainted with the goals of the Go-Lab project.	20 min.
Basic concepts	A short explanation of basic concepts related to online labs and the inquiry-based learning approaches to science education.	10 min.
Example	A short look at an example activity making use of "*How long does a day last in Jupiter*" on-line laboratory showing the use of a remote lab in combination with theoretical background and educational resources.	10 min
Mockup	A brief description of the early design of the Go-Lab Portal and of the pedagogical structure as well as learning tools as illustrated by the interactive mockups.	10 min.
Federation of labs	A brief explanation of the need for the federation of online labs.	10 min

Table 5. Overview of the content of the Go-Lab project presentation for the long PD workshop

3.2.2.3 Prototype Evaluation

The initial design concepts of integrating the Go-Lab inquiry learning cycle into online labs are evaluated using the Balsamiq tool, producing interactive mockups of the three so-called anchor labs with the associated learning activity (details see D1.1):

- HYPATIA: *Conservation of Momentum* mockup for upper secondary schools
- Faulkes Telescope: *Interacting Galaxies* mockup for lower secondary schools
- Aquarium Web Lab: *Buoyancy* mockup for primary schools

For evaluating these mockups, two approaches were selected: (i) *Online*: the Balsamiq online modification tools; (ii) *Paper-based*: Layered Elaboration with mockup printouts.

Online: Participants are provided with computer access and work individually or as a small group of 2 or 3 people. They are introduced to one of the three mockups, depending on the school type and level to which they belong, and it is demonstrated how to modify the mockups using different tools provided in the Balsamiq editor (Figure 18). Among them, the yellow "virtual stickies" tool (Druin, 1999) for making comments is deemed intuitive to use as it simulates everyday practice. The participants are then given a use scenario specific to the mockup to follow. They progress on their own pace within a 45- or 60-minute timeslot when they are asked to provide comments and improvement suggestions for the design of the interfaces that would better meet their needs and goals. The online comments so gathered can be accessible to the Go-Lab development team.
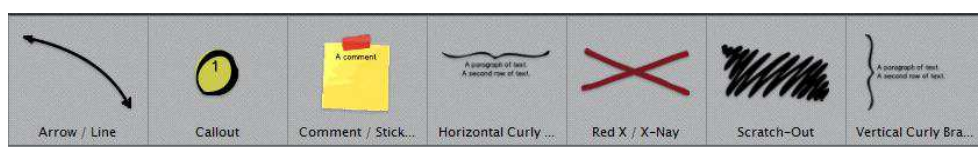
Figure 18. The Balsamiq editor modification tools for providing comments

Paper-based: Layered Elaboration is a more recent paper-based prototyping technique proposed by Walsh *et al.* (2010), which is simple to apply, and has the feature of keeping comments from an iterative process intact. It also enables researchers to identify the features most commented on by overlaying the different acetate sheets. The individual evaluation using Layered Elaboration starts by providing each participant with a use scenario (depending on the school type and level they are teaching), printouts of the mockups, and acetate sheets for comments. After the researcher briefly

describes the task by going through the scenario and demonstrating the superimposed printouts and acetate sheets, the participants are asked to read through the scenario, clarify any questions they have and run the scenario. Participants provide feedback by annotating the acetate sheets with textual comments, drawings/sketches of their ideas or any other appropriate means (Figure 19). The acetate sheets so gathered are sorted according to the mockup screen to which they belong and then placed on top of each other on the screen printout.
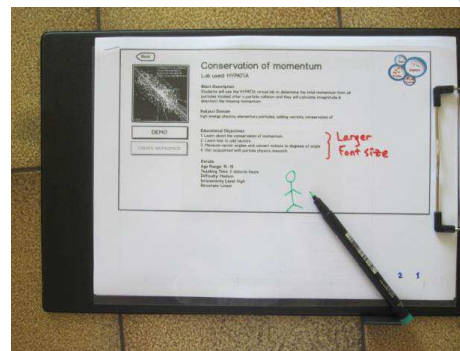
Figure 19. Layered elaboration toolset

3.2.2.4 Group Discussion

After the prototype evaluation participants were engaged in one of two alternative activities in the group discussion phase: Selecting Design Options or Focus Group.

Selecting Design Options: With the basic understanding of the Go-Lab concepts and their own related educational experiences, the participants should be able to make informed decisions among the given design options for different components of the Go-Lab online labs. Divided into small groups of 3 or 4, they are given a set of two or three printouts showing the design options for a specific feature of the online lab interface (see example in Figure 20) and asked to select one of the options and annotate it with pros and cons for the selection. When all the groups complete all the selections required, a delegate from one group presents their selected option and associated reasons to the plenum. Such results are recorded using a report template or audio-taped.
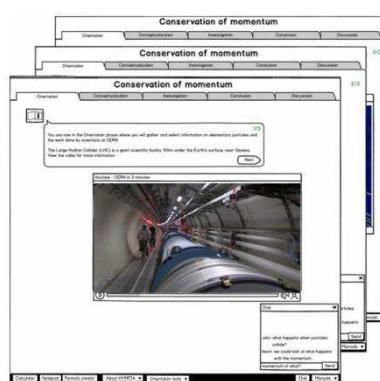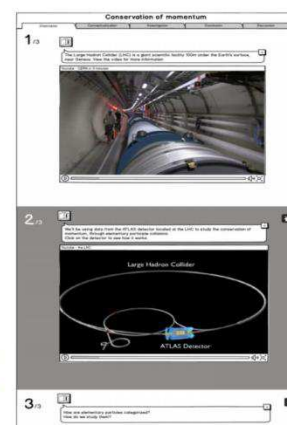
Figure 20. An example of alternative design options

Focus Group: It is carried out as a semi-structured group interview, where the researcher acts as a moderator to facilitate the discussion among a group of people on certain topics. The main goal is to encourage the participants to share their thoughts and feelings with regard to online labs. A focus group is structured by discussion topics including the Go-Lab portal adaptation, its content and access to the portal and supported by a set of questions for each topic. All discussions were audio-taped and the records transcribed for further analysis.

3.2.2.5 Summary

Postcard is the final activity to promote the connection between users and developers by sharing artefacts (postcards). Each participant is given a "postcard" and asked to write a "postcard to the

designers" including one positive and one negative aspect of the Go-Lab online labs, in form of a question or thought.

3.2.3 Overview of data collection in PD workshops

Two sources of data are collected for PD workshops. The first is the same reporting scheme used for VWs (Section 3.1.3) to record the logistic information of the PD workshop as well as organizers' observations and perceptions of the event. The second, which is more important, is participants' direct feedback captured during different kinds of PD activity (Section 3.2.2); some data are digital such as online comments recorded by MyBalsamiq and some are paper-based such as annotated printed mockups, design option templates and postcards.

3.3 Pedagogical Framework Research Questions

The pedagogical team of Go-Lab have formulated a set of research questions (RQ) to evaluate the design options for the user interface of the selected online labs (Section 3.2.2.3) with the aim to inform its redesign and to refine the pedagogical framework.

The participatory design team selected the applicable methodology to address the RQs and the questions that can be answered in this round of PD activities are shown in Table 6. The other RQs (D1.1) can be addressed by the PD workshops at later stage of the project, when interactive prototypes are available.

The RQs addressed by the PD activities were grouped into categories of questions that are similar in nature. Applying the content analysis techniques (Krippendorff, 2004; Weber, 1990) to the empirical data collected through the two key PD activities - Prototype Evaluation (Section 3.2.2.3) and Group Discussion (Section 3.2.2.4), answers to individual RQs were derived.

Category	Research Questions (RQs)
Navigation	*RQ1*: Do we need a graphical overview of the inquiry phases or are the current tabs sufficient? *RQ2*: Is there a preferred sequence through the phases or should students be able to move freely between phases? *RQ3*: Should students be able to start free experimenting, without an orientation? *RQ4*: Should all inquiry phases be available or should some of them be greyed out? *RQ5*: Should navigation between phases only be possible through the tabs?
Discussion phase	*RQ6*: Should students do a reflection per phase or perform all reflection at the end? Same question refers to reporting.
Window layout	*RQ7*: Should we make more separate windows to avoid information overload? *RQ8*: Should all the information be presented in one scrollable window (or tab between windows)?
Toolbar location	*RQ9*: Where is the best location of the toolbar?
Working offline	*RQ10*: Should some phases be done offline?
Lab description	*RQ11*: Is the lab description at the start sufficiently informative?
Guidance adaptation	*RQ12*: Can help for a tool be represented by a small button (with a lightning bulb or question mark) on each tool or do students prefer the help at the top of the page describing what to do with each tool? *RQ13*: How much should the guidance be adapted to age level or student competence? (Is the level of support the same for all students, domains, topics, or should this be adaptable (e.g., through fading)? *RQ14*: Are the general tools adequate or is something missing or useless? For example a (dedicated) notebook for the students (e.g., to write down their answers to specific questions)? *RQ15*: Should students be able to make changes in a scaffold from a previous phase or

| | should this be restricted to a specific phase and should all scaffolds be available in all phases (bottom tab)?
RQ16: Are there forms of guidance/scaffolds that are currently missing? |

Table 6. Pedagogical research questions addressed by the PD activities

4   Results: Eliciting and Analyzing Multi-source Data

This section describes the methods for analysing the multisource data collected during the participatory activities of VWs and PD workshops, and reports the main results.

4.1   Visionary Workshops

4.1.1   Implementations of VWs

25 VWs were organized in 9 European countries and their characteristics are summarized in Table 7.   All VWs except one were carried out face-to-face as a half-day or an evening event. The participants were mostly science teachers, who were representatives of the region where the workshop was held or of the entire country where it was organized. The participants of only one online VW were an international community of teachers.   One of the workshops hosted seven students of the master programme for training secondary schools teachers of STEM.

Date	Organizer	Location	Participant	Language	Implemented online labs	Discussion	Survey
2.3.	EUN	France, Tours	28 teachers	English	Faulkes Telescopes, Aquarium Web Lab, HYPATIA, Sun4all, CERNland	Yes	Yes (WP6)
2.3., 16.3.	NUCLIO	Portugal, Gaia	20 teachers	Portuguese	Salsa J, Faulkes Telescope, Sun4all, World Wide Telescope, CosmoQuest, Celestia and Stellarium	Yes	No
3.3., 17.3.	NUCLIO	Portugal, Gaia	20 teachers	Portuguese	Salsa J, Faulkes Telescope, Sun4all, World Wide Telescope, CosmoQuest, Celestia and Stellarium	Yes	No
6.3.	EA	Greece, Komotini	43 teachers	Greek	HYPATIA and Faulkes telescopes	Yes	Yes (WP6)
8.3.	UCY	Cyprus, Nicosia	17 teachers	Greek	Stellarium	Yes	Yes (WP6)
10.3.	EUN	Spain, Madrid	30 teachers	English	Faulkes Telescopes, Aquarium Web Lab, HYPATIA, Sun4all, CERNland	No	No
21.3	UTE	Estonia, Tartu	30 participants	Estonian	http://bio.edu.ee	No	No
23.3., 25.3.	NUCLIO	Portugal, Cascais	10 teachers	Portuguese	Salsa J, Faulkes Telescope, Sun4all, World Wide Telescope, CosmoQuest, Celestia and Stellarium	Yes	No
23.3., 25.3.	NUCLIO	Portugal, Quarteira	20 teachers	Portuguese	Salsa J, Faulkes Telescope, Sun4all, World Wide Telescope, CosmoQuest, Celestia and Stellarium	Yes	No
6.4., 8.6.	NUCLIO	Portugal, Coimbra	20 teachers	Portuguese	Salsa J, Faulkes Telescope, Sun4all, World Wide Telescope, CosmoQuest, Celestia and Stellarium	Yes	No
11.4.	UT	Netherlands, Utrecht	5 participants	Dutch	n/a	Yes	No
16.4.	UDEUSTO	Spain, Bilbao	7 MSc students	Spanish	Aquarium WebLab	Yes (Aquarium)	Yes (Aquarium WP6)
18.4.	EA	Greece, Pallini	40 teachers	Greek	Google Earth, Stellarium, Faulkes robotic telescopes, crashing galaxies simulator, Hypatia, CMS experimen	Yes	Yes (WP6)
23.4.	EUN	Online	10 teachers	English	Faulkes Telescopes, Aquarium Web Lab, HYPATIA, Sun4all, CERNland	Yes	No
26.4.	UDE	Germany, Duisburg-E.	5 teachers	German	Faulkes Telescopes, Aquarium WebLab, HYPATIA, Munich RCLs	Yes	Yes
2.5.	UDEUSTO	Spain, San Sebastian	15 teachers	Spanish	Aquarium WebLab	No	Yes (Aquarium WebLab)
4.5., 20.5.	NUCLIO	Portugal, Aveiro	20 teachers	Portuguese	Salsa J, Faulkes Telescope, World Wide Telescope, EUHOU radioantenas	Yes	No
7.5.	UDEUSTO	Spain Bilbao	22 teachers	Spanish	Aquarium WebLab	No	Yes (Aquarium WebLab)
11.5.	UDEUSTO	Spain, La Coruna	11 teachers	Spanish	Aquarium WebLab	No	No
20.5.	EA	Greece, Chania	30 teachers	Greek	Faulkes Telescopes	Yes	No
27.5.	EA/ CERN/ UDEUSTO	Spain, Barcelona	13 teachers	English	HYPATIA and Aquarium WebLab	No	No
27.5.	CUAS	Austria, Bregenz	13 participants	German	CUAS VISIR Lab	No	No
28.5.	EA/ CERN/ UDEUSTO	Spain, Bilbao	37 teachers	English	HYPATIA and Faulkes telescopes	No	No
4.6.	CUAS	Austria, Klagenfurt	19 participants	German	CUAS VISIR Lab	No	No
11.7.	UDE	Germany, Duisburg	4 teachers, 1 student	German	Faulkes Telescopes, Aquarium WebLab, HYPATIA, Munich RCLs, Labster	Yes	Yes

Table 7. An overview of twenty-five Go-Lab Visionary Workshops in nine countries

An example of an event agenda at one of the locations is shown in Table 8 and some activities carried out during VW are illustrated in Figure 21a and 21b.

Time	Activity
17.30 – 18.00	Remote Laboratory, visiting WebLab-Deusto
18.00 – 18.15	Go-Lab Project build federation of science labs
	• How long does a day last in Jupiter
	• AquaLab and Archimedes Principles
18.15 – 19.15	Ideas of the future – Designing my own experiment in Go-Lab (work in groups)
19.15 – 20.00	Comments, Discussion, Survey

Table 8. An example agenda of a VW

Figure 21a. Go-Lab VW in Tours, France, March 2013

Figure 21b. Go-Lab VWs in Bilbao, Spain, May 2013 (left) and in Komotini, Greece, March (right)

4.1.2 Methodology for Data Analysis for VWs

4.1.2.1 Go-Lab Portal and Pedagogical Guidance

Combining the data from individual VWs can result in a consolidated stakeholders' view on the future of science education and on the pedagogical, organisational and technological aspects of Go-Lab. All reports from the first round of VWs were collected and analysed. Participants' opinions could be derived from the discussions and surveys carried out in the last phase of each workshop. The analysis of the discussion activity included highlighting keywords in the discussion section of each report. Based on such keywords, categories of discussion topics were derived. For each of the categories the related paragraphs were extracted from the original reports and then summarized. The survey results were also consolidated with respect to individual questions (Section 4.1.3).

4.1.2.2 Organizational and Technical Barriers for Online Labs Use

Two of the questions in the VW survey are of particular relevance: *"What are most important problems that have to be dealt with in order to integrate the use of online labs in the curriculum?"* (Question 9) and *"How can we overcome these problems?"* (Question 10). The responses to these two questions and the data captured by the VW reports were segmented into units of analysis (Krippendorff, 2004), which were categorised in terms of types of barrier. For individual categories thus identified, the total frequencies over all the VWs were counted and were elaborated with the related comments of the participants (Section 4.1.4).

4.1.3 Results of VWs: Go-Lab Portal and Pedagogical Guidance

This section consists of two sub-sections. Results from the discussions expressed mostly by teachers during fourteen VWs are reported in the first sub-section (NB: the locations of the VWs from which the results were derived are listed in square brackets), and results from the VW survey are presented in the second sub-section.

4.1.3.1 VW Discussions

General: The VW participants appreciated the idea of online labs federation, the level of detail of the presented anchor labs and the direction the tool seems to be taking. Teachers not experienced with online labs were interested to find out more information and to discover laboratories matching their needs while the experienced teachers wanted to learn more about the platform. [Tours, Pallini, Online, Chania]

Scenarios: For the VW participants, an online lab, when designed with the inquiry-based science education (IBSE) methodology, is a motivating apparatus for engaging students to study science. They recognized the potential of the labs to enable students to discover nature's phenomena in different ways, promoting critical thinking, more profound understanding of science topics, and acquisition of key ICT skills. Most of the participants expressed willingness to use the online labs demonstrated in teaching and let the students experience the same tools that scientists use, for instance Faulkes Telescope and SalsaJ. Some participants even envisioned teaching via videoconferencing, when students work remotely using their own computers at home. [Gaia I, Gaia II, Quarteira, Cascais, Coimbra, Aveiro]

Interface: Although the teachers found the mockups well organized with logical structure, it was emphasized that a simpler interface would be more suitable for the students. For example using simple graphics, small icons, colours and short instructions instead of large paragraphs of text would attract the attention of students, avoid overloading them, and help them find the features easily. A requirement for a more playful platform interface and lab appearance was stated, because the students nowadays were said to prefer more game-full learning process. Game-based activities aiming to assess student knowledge were also suggested. [Tours, Komotini, Nicosia, Online, Chania]

Training requirements: The majority of the teachers agreed that it would be helpful to have some form of training before using the platform either as a workshop or having access to a common test area of the portal where they can try things out and communicate with other teachers. Small helpful tips, short screen casts and online user guides on performing various tasks in the environment would be appreciated by the teachers who prefer the smaller but continuous help to large user guides. [Tours, Komotini, Nicosia, Pallini, Online]

Go-Lab portal: The information presented on the Go-Lab portal front page and in labs description was considered sufficient. The teachers remarked that the search criteria/filters matched their

expectations (i.e., labs and activities categorized by subject and age). In addition they preferred the information about the difficulty level to be provided, because not all students of the same age have the same skills and level of performance. When selecting a lab, teachers would be interested in reading comments and scores from other portal users, and they would also like to see suggestions of activities that could be carried out after they completed the activity they had chosen; this could help them carry out a series of experiments without the need of additional search. [Komotini, Pallini, Chania]

Scaffolds: The presence of scaffolds was regarded as very valuable for science education by all the teachers. However, the teachers would like to control when scaffolds are provided (e.g., scaffolds would be shown after a student makes an effort and requests for help) and to have the flexibility to edit the content and to add new scaffolds. The teachers pointed out that the current remote labs do not provide the possibility of making errors in the experimental setup, which can happen easily in the real life experiments. Some teachers were worried whether the students could manage current scaffolds. The scaffold that appeared to puzzle them the most was the "Concept map tool". The teachers also appreciated the integration of the inquiry-based model through the different steps but they all agreed that some support would be needed. Explanations of the inquiry-based model should be easily accessible throughout the process. There was also a need to be able to adjust the same activity for the different levels of their students. For example, the teachers would like to have the option to include more than one version of the same worksheet. [Komotini, Pallini, Nicosia, Online, Chania]

Utilizing and creating activities: Some common opinions were expressed concerning the use of the online labs currently included in the Portal, especially the level of support for adapting them, varying from modifying the existing activities to their needs to creating new activities in the Go-Lab portal. Summing up the opinions documented in the surveys, the ideal option would be to provide both the access to the existing activities and the flexibility to change them or add new ones. In either case, the participants believed that having the opportunity to design educational activities with expert scientist and educators would be of great benefit for both teachers and students. Moreover, some teachers seemed to be quite intrigued by the possibility to link to teachers, experts and scientists from all over Europe. Upon discussing how they would imagine implementing such activities within their school, many participants agreed that in some cases such activities would be useful to replace the homework currently given to students. [Komotini, Chania, Online]

4.1.3.2 VW survey: the online labs use

Tables 9a-h summarize the responses to the questions of the VW survey, which was conducted in some but not all VWs (Table 7).

Question 1: *Do you use on-line labs in your school?*

Country	Yes *(n)*	No *(n)*
France (N=17)	3	14
Greece (N=83)	30	53
Cyprus (N=13)	1	12
Spain (N=6)	6	0
Germany (N=9)	1	8
Total	**41**	**87**

Table 9a. Results of the VW survey Question 1

Question 2: *How often do you use online labs in your school?*

Country	Once a week	Once a month	More than once a month	Other	N/A
France (N=17)	4	0	1	0	12
Greece (N=75)	4	7	13	12	39
Cyprus (N=13)	0	0	1	10	2
Spain (N=6)	0	0	0	0	6
Germany (N=9)	0	0	0	2	7
Total	**8**	**7**	**15**	**24**	**66**

Table 9b. Results of the VW survey Question 2

Question 3: *Do you cooperate with other teachers during the implementation of the activities which include the use of online labs?*

Country	Yes *(n)*	No *(n)*
France (N=17)	8	9
Greece (N=54)	7	47
Cyprus (N=13)	3	10
Spain (N=6)	4	2
Germany (N=5)	0	5
Total	**22**	**73**

Table 9c. Results of the VW survey Question 3

Question 4: *Is it easy to find online labs on the internet?*

Country	Yes *(n)*	No *(n)*
France (N=17)	8	9
Greece (N=65)	38	27
Cyprus (N=13)	7	6
Spain (N=6)	5	1
Germany (N=4)	3	1
Total	**59**	**44**

Table 9d. Results of the VW survey Question 4

Question 5: *Would it be useful to have a digital library with educational online labs?*

Country	Yes *(n)*	No *(n)*
France (N=17)	11	6
Greece (N=74)	74	0
Cyprus (N=13)	13	0
Spain (N=6)	6	0
Germany (N=8)	8	0
Total	**109**	**6**

Table 9e. Results of the VW survey Question 5

Question 6: *How do you believe they should be organized in such a digital library?*

Categories	CY	FR	GR	ES	DE	Total
Subject domain (e.g., Physics, Chemistry, Biology etc)	1	2	24	0	0	**27**
Unit (e.g., living things, forces etc)	3	0	0	0	0	**3**
Specific topic (e.g., rotational motion, electrical circuit, etc)	6	1	0	0	6	**13**
Curriculum of each country	2	0	7	6	6	**21**
Age of students	5	2	26	0	4	**37**
Language	3	0	0	0	0	**3**
Level of difficulty	0	0	21	2	5	**28**
Preparation/Implementation time	0	0	4	0	0	**4**
Instructional design	0	0	0	2	0	**2**
Object type (e.g., video, excel file)	0	0	0	0	3	**3**

Note: Data from the 5 countries were categorized; a participant's response may contain more than one category.

Table 9f. Results of the VW survey Question 6

Question 7: *Would it be useful to have access to educational activities that include the use of online labs or would you prefer to create your own?*

Country	Have access to activities (n)	Design my own activities (n)	Both (n)
France (N=17)	3	3	7
Greece (N=74)	34	11	29
Cyprus (N=13)	7	0	6
Spain (N=6)	0	0	6
Germany (N=12)	6	5	1
Total	**49**	**19**	**49**

Note: Four participants in the workshop in France answered this question "Yes" instead of indicating the preference. These answers were excluded from the count.

Table 9g. Results of the VW survey Question 7

Question 8: *Would it be useful to create activities in cooperation with experts?*

Country	Yes (n)	No (n)
France (N=16)	16	0
Greece (N=74)	74	0
Cyprus (N=13)	12	1
Spain (N=6)	6	0
Germany (N=8)	8	0
Total	**116**	**1**

Table 9h. Results of the VW survey Question 8

4.1.4 Results of VWs: Organizational and Technical Barriers to Online Labs Use

Different organizational and technical barriers may hinder teachers from using online labs (cf. Question 9 and Question 10 of the VW survey; Section 4.1.2.2). Based on the comments made by the participants of the VWs, such barriers were identified, categorised and sorted in terms of frequency (Table 10). Individual barriers and their possible solutions proposed by the participants are discussed subsequently.

Type of Barrier	Freq.	Type of Barrier	Freq.
Usability problems and content issues	28	Lack of experience with online labs	8
Limited access to the Internet and ICT	28	Ready-made solutions with low modifiability	6
Lack of time and curriculum match	17	Difficult search for online labs	4
Lack of training	14	Insufficient funding	3
Student management issue	9	Inadequate school support	2

Note: The frequency excludes the number of participants from VWs in Portugal, because the data was not available.

Table 10. The categories of organizational and technical barriers derived from the VW data.

4.1.4.1 *Usability problems*

It was mainly referred to the rather complex user interface of the labs containing large amount of textual information that was simultaneously displayed on multiple locations of the screen and it was not clearly separated by borders or distinguished by colours. Besides, the need to support students with different skills and special needs was expressed by the participants. Some tools were found difficult to understand (e.g., the concept map) or some were not so attractive (e.g., the reporting). Furthermore, most labs are available only in English language and this can limit their use in other European countries. Ideally multilingual labs and materials or localized guidelines with some examples on the online labs use should be provided.

The teachers underlined the need to have a simple interface with simple graphics, short paragraphs of text, and minimum number of windows in each phase because not everything needs to be displayed at the same time. It would help students find services and make the interface more attractive for them. People with special learning needs should be taken into account when designing online labs, for example, by indicating the lab difficulty level. Furthermore, the instructions for the 'concept map' tool should be more detailed, and it should also appear at the end of the inquiry cycle for the assessment purpose.

4.1.4.2 *Content issues*

It was pointed out that the terminology used in the labs would be too difficult for a particular target group of students to understand, especially if they may not be familiar with the scientific terms such as factors, variables, properties, fluids and other numerical jargon or with the complex terms used in the instruction of the online lab mockups. Besides, the participants remarked that some information is missing such as the information that can facilitate the understanding of a topic and that can be shared between the Portal users (e.g., "comments and votes"). Some participants commented that it is important to evaluate the need for online labs as compared with real-life labs, because using online labs may not be very helpful if the activities can be carried out with simple materials in the classroom. To make the most of the online labs use in science education, the developers should focus on those labs which are difficult to carry out in the classroom (e.g., nuclear physics, radioactivity, zero gravity).

To address the issue of complexity and to ensure that the terminologies used are coherent with how they are used in the national curricula, provision of a glossary for the scientific vocabulary could be a solution. For the Go-Lab mockups, the distinction between the inquiry cycle phases (e.g., orientation and conceptualization) was not clear and some teachers suggested that a short description should be provided concerning the different purpose of each phase.

4.1.4.3 Lack of training

Many participants would prefer to have training before using an online lab for teaching or follow the instructions during the lab use. The reasons for the training requests were mostly insufficient experience with ICT in general and online labs in particular. A single case suggested some form of training for teachers who may have negative attitude to the use of ICT for teaching. The training would become a part of their professional development and ideally carried out in coordination between teachers and lab owners to exchange ideas for improvement. To get familiar with the platform for performing various tasks, the teachers should be given access to a common test area where they can try things out and communicate with other fellow teachers. Alongside the teachers' training, students should be given the opportunity to get familiar with online labs environment to make the learning of a specific content more efficient. Besides, the teachers remarked that it would be much more efficient to have small bits of helpful information throughout the portal than huge user guides, which might become out of date quickly and be unusable. However, other teachers expressed the need for online tutorials or printed guidelines. Finally, the language skills were seen as an obstacle to the use of online labs in different languages. To overcome this obstacle, a solution proposed by the teachers is to integrate their own labs into the portal.

4.1.4.4 Lack of time and curriculum match

Time has often been cited by teachers as the obstacle for using online labs in education. Teachers would need extra time to prepare a lesson plan to include the use of online labs, and to learn about the labs. The time issue is closely related to curriculum, which currently does not provide optimal conditions to accommodate the use of online labs. Moreover, curricula vary across the European countries, calling for online labs that could fit all the educational systems. Besides, there were comments that biology, chemistry and mathematics teachers generally have limited access to the online labs, as they are simply not available. Students near their final exams or their parents may be less motivated to use online labs, because they would prefer preparation for the exams, which employs a different methodology than the online labs. To mitigate the issue of curriculum mismatch, the content design of an online lab should be based on the curriculum but not as detailed as per book chapter because books change quite often and new principles of student evaluation should be introduced to enhance adoption.

4.1.4.5 Limited access to the Internet and ICT

One of the technical problems repeatedly stated by the teachers was the Internet access. The teachers reported difficulties primarily with the reliability and low bandwidth of the Internet connection at schools. Another technical barrier is the access to ICT. For example the limited number of computers in a class, the low processing power of computers (dated models) or lack of permissions for software installation can limit the number of students that can simultaneously access an online lab activity. An alternative suggestion was to have an offline version of the online labs.

4.1.4.6 Lack of experience with online labs

A number of teachers have never used a remote laboratory. There may be a general awareness about online labs among the teachers and some have already used it in their classes, but the data from several workshops show that the number of teachers who are actively involved in the use of online lab is quite low. An introduction to the Go-Lab project and online labs being integrated can be an effective solution to overcome the lack of experience with online labs.

4.1.4.7 Ready-made solutions with low modifiability

The teachers acknowledged the help of virtual/remote labs for teaching complex phenomena. They appreciated the existing ready-made solutions, because of the difficulty to create the online labs on their own. But most teachers required having the possibility to modify these activities based on

their needs. Specifically, they preferred to design educational activities with expert scientists and educators and have access to online labs/activities that have been put together by other teachers. The suggestions for modification of the Go-Lab portal and online labs focused primarily on the possibility to control the deployment of scaffolding tools and functions. The teachers would prefer to be able to define what functions and tools appear in each phase or when scaffolds would be shown, to have the flexibility to edit their content and to be able to add new scaffolds. For example there is no need for a calculator in the discussion phase or scaffolds can be launched after students have made an effort on their own and have requested help.

4.1.4.8 Difficult search for online labs

The teachers proposed that it would be useful to have a digital library with educational online labs. Furthermore, the teachers would mobilise help from students who have the required skills to locate a remote lab on the web efficiently and effectively.

4.1.4.9 Insufficient funding

The financial issue is closely related to the previously discussed barrier on the ICT and Internet access. Obviously, the primary solution would be increasing the funding for technological infrastructure by some means.

4.1.4.10 Student management support issue

Online labs should provide appropriate monitoring of students' progress (real-time or post-exercise) and support the organization of the student work in the classroom (i.e., students involved in individual or group work). The number of students per class can play a role in the online labs adoption. Some teachers complained that the number of students in the class would be too large for managing this activity and that the simultaneous use of a remote lab by several students might not always be possible.

4.1.4.11 Inadequate school support

Inadequate school support can be seen as another organizational barrier for the wider use of online labs. Although most schools allow their teachers to use online labs and in some exceptions support it, the teachers have reported that they would prefer more support and encouragement for this activity. Schools can share some of their success stories and follow the examples of others including teachers' experience.

4.1.5 Reflection on VWs

As evident by the rich results described above, VWs could fulfill their goals and objectives to a large extent. Participants were not only demonstrated the emerging design of online labs but also given the opportunities to reflect on their current science teaching environments, thereby providing improvement suggestions for the future development of the Go-Lab Portal. In addition, VWs laid the important groundwork for the participants to build the community that could support the continuous professional development of the teachers and the sustainability of the work of Go-Lab.

Clearly, there are still a range of personal, social, technical and organizational issues to be addressed for the mass uptake of online labs. To gain more insights into the facilitating and hindering factors for the integration of online labs into the existing curricula and real practices, teachers should be invited to develop scenarios on deploying online labs in their everyday teaching. This objective is to be realised in the next phase of the Go-Lab participatory activities.

4.2 Participatory Design Workshops

In parallel to VWs, Participatory Design (PD) workshops were conducted to collect different stakeholders' feedback on the pedagogical framework and technical development of the project, thereby gaining insights into the improvement of the ongoing work in Go-Lab.

4.2.1 Implementations of PD workshops

Project partners have developed new contacts as well as utilized the existing ones to organize the first round of PD workshops in the period of M6-M9 (May – August 2013). The summary of the events including date, location, participants and implemented online labs is shown in Table 11. The activities were conducted in the locality of participating group (e.g., school), in a research environment (e.g., university), or in a "third space" (e.g., conference workshop). The participants - 195 teachers and 43 students from primary and secondary schools - mainly evaluated the initial design concepts using the interactive mock-ups of three so-called anchor labs with associated activities: HYPATIA: Conservation of Momentum; Faulkes Telescope: *Interacting Galaxies*; Aquarium Web Lab: *Buoyancy*.

Date	Organizer	Location	Participants	Duration	Mockup used
29.5	UCY/EPFL	Limassol, Cyprus	15 secondary and 5 primary teachers	3 hours	HYPATIA
20.6	ULEIC	Northamptonshire, UK	10 teachers and 13 students (Year 12)	2 hours	Faulkes Telescopes
21.6	ULEIC	Staffordshire, UK	2 teachers and 2 students (Year 8-9)	2 hours	Faulkes Telescopes
1.7	ULEIC	Leicestershire, UK	28 students (Year 5)	2 hours	Aquarium Web Lab
1-3.7	UTE	Nelijärve, Estonia	50 teachers	2 hours	Go-Lab Portal
4.7	ULEIC	Leicestershire, UK	4 teachers (focus groups)	2 hours	HYPATIA
10.7	ULEIC/CERN	Geneva, Switzerland	51 teachers	3 hours	HYPATIA
30.7	EA/EPFL	Volos, Greece	25 teachers	2 hours	HYPATIA
3.8	EA/EPFL/ULEIC	Volos, Greece	33 teachers	2 hours	HYPATIA

Table 11. Overview of Participatory Design (PD) Workshops

All the above workshops were conducted in English except in Cyprus where a mix of English and Greek was used and in Estonia where the local language was used. As most of them followed the PD protocol described in Section 3.2.2, here we briefly describe the two, namely Cyprus and Estonia, which were somewhat different from the 'standard' ones.

PD workshop in Cyprus: It was co-organized by UCY and EPFL as a part of the JTEL Summer School, and was actually a hybrid of VW and PD. It lasted three hours and involved 15 secondary and five primary school teachers. The VW part emphasized the need for improving science education using new and attractive science instructions and online labs. The idea of the Go-Lab project was presented.

Figure 22. Go-Lab Participatory Design Workshop in, Limassol, Cyprus, in May 2013

For the PD part, the participants were divided into five small groups to discuss the paper-based mockups of the Go-Lab portal and HYPATIA. Each group was assigned a different phase of the online lab as a focus of evaluation (Figure 22). After the completion of the PD activity, each group had the opportunity to provide their comments, advantages and disadvantages of the "HYPATIA/Conversation of Momentum" mockup as well as improvement suggestions for the phase

they were assigned to. A more general discussion at the end of the workshop allowed all groups to provide their feedback for all issues emerged.

PD in Estonia: The event involved group of 50 teachers and students from secondary schools and university and consisted of two one-hour slots. A short project introduction was given in the first hour slot and in the second hour a systematic evaluation of the initial Go-Lab mockups translated into Estonian was carried out using the computer-based method. Finally participants were given the opportunity to fill a Google form message to the prototype designers.

4.2.2 Methodology for Data Analysis for PD Workshops

The initial round of PD workshops produced rich participants' feedback to the design concepts of the Go-Lab portal and inquiry cycle for the selected online labs. The feedback was collected from two sources: (i) Participants: Providing elaborate feedback on an individual basis, elicited as a result of applying the PD methods such as Layered Elaboration, Virtual Stickies, Selecting Design Options and Postcard; (ii) Organizers: Summarizing the activities carried out in the workshops. The data analysis approach for individual PD methods used is described in the following.

4.2.2.1 *Layered Elaboration*

The Layered Elaboration technique was used to capture the feedback of participants who were required to annotate the acetate sheets superimposed on the mockup printouts. In order to make the results accessible for the project members involved in the portal development, results were digitized and consolidated per mockup. In this process the acetates were scanned and stored as image files. The files including comments were then cleared of the background image, leaving only comment that were layered on top of the original mockup screen using an image manipulation program. The program allows controlling the visibility of each layer, and by displaying multiple comments the main points of interest can be identified in the picture. The comments overlay for a certain phase of the inquiry cycle is demonstrated in Figures 23a and 23b.
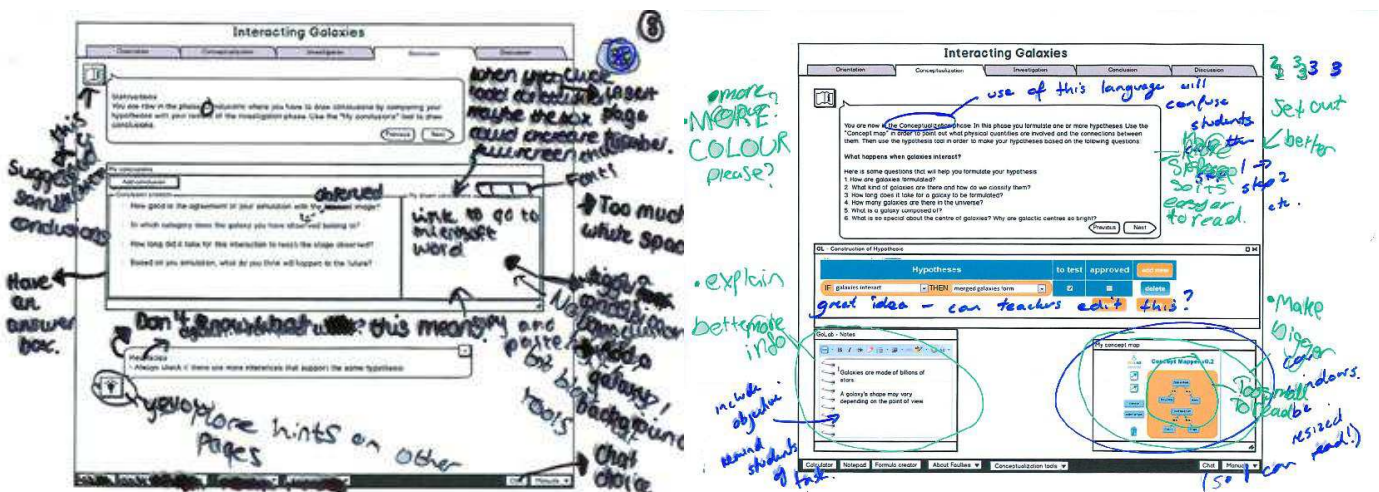
Figure 23a (left). Multiple participants' comments (all using black marker) point to the "My drawn conclusion" tool (middle-right position).
Figure 23b (right). Multiple participants' comments point to the "My concept map" tool (bottom-right position).

4.2.2.2   Virtual Stickies

In the Balsamiq online mockup tool, participants could use virtual stickies (cf. yellow Post-in notes, Figure 18) to make comments, which can be accessed digitally. However, individual participants may comment every screen of a mockup (e.g., HYPTIA/Conversation of Momentum consists of 12 screens), resulting in a large number of annotated screens. To enhance the efficiency of data analysis, the Layered Elaboration technique was adapted for handling these virtual stickies. Specifically, a participant's comments for a mockup were extracted and stored as an image file. Then the process identical to producing the layered view of all participants in a PD workshop (Section 4.2.2.1) was implemented. An example is shown in Figure 24.
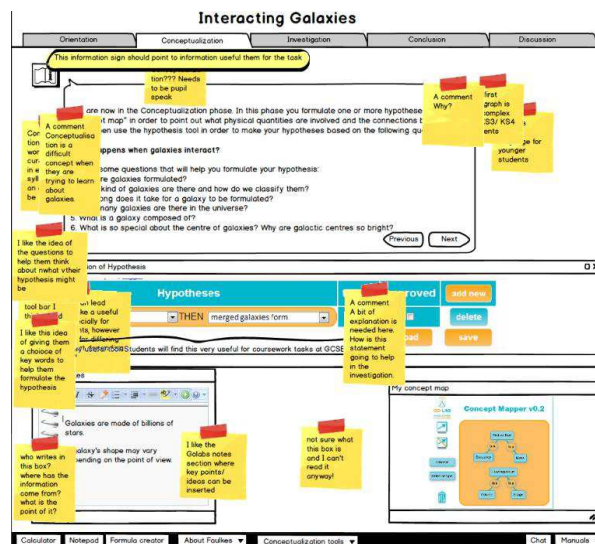
Figure 24. Multiple participants' comments to the Instructions and Hypothesis tool.

4.2.2.3   Selecting Design Options

The participants expressed their opinions for the decision between given design options (Section 3.2.2.4), both orally and by written comments written on the mockups or a template. Orally presented comments were recorded and transcribed or noted down during the discussions. The number of 'votes' per option was tallied.

4.2.2.4   Postcards

Through the final activity of the PD workshop, the most positive and negative comments on the Go-Lab Portal highlighted by individual participants in the form of a postcard (Figure 25) were collected.
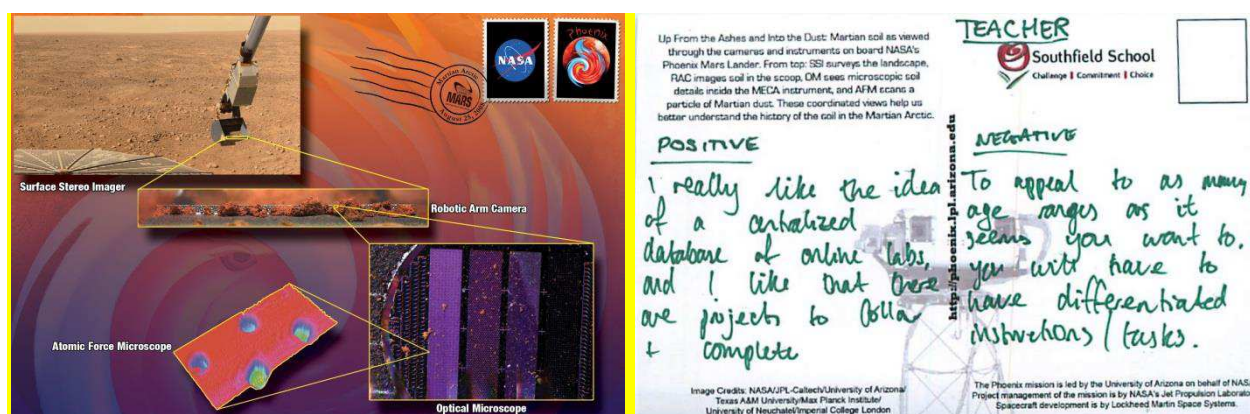
Figure 25. Postcards for highlighting user perceptions of Go-Lab.

4.2.3 Results of PD workshops: Pedagogical Framework RQs

To answer the Pedagogical Framework research questions (RQs) (Section 3.3), the data from the PD activities - Selecting Design Options, Layered Elaboration and Virtual Stickies - were used (Section 4.2.2). For each RQ, a short answer (A) summarizing the findings is provided. The data are organized in the following sub-sections corresponding to the seven categories of the pedagogical research questions. Those that do not fit to any of the categories are placed in the "General Online Lab Remarks" sub-section. The final sub-section "End-user feedback for the designers" provides direct feedback sent from the teachers and students to the Go-Lab Portal designers and developers using the postcards in PD Activity "Summary" (Section 3.2.2).

4.2.3.1 Navigation

- **RQ1:** Do we need a graphical overview of the inquiry phases or are the current tabs sufficient?
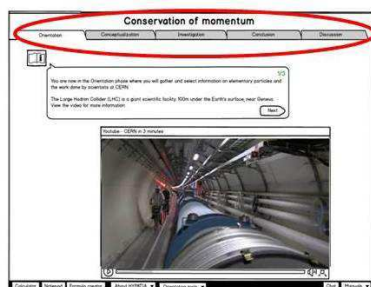- **A1:** The tabs representation is preferred by teachers and students.

Date source: *Selecting Design Options - Tabs vs. Circle*

Printout 7 – inquiry cycle phases represented by the tabs
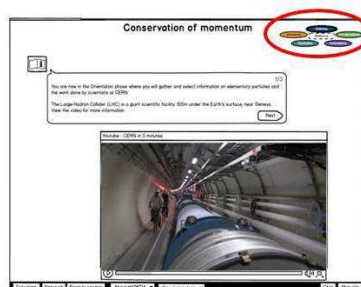
Printout 8 – Inquiry cycle phases represented by the circle

Navigation	Teachers	Students
Tabs	**72**	**18**
Cycle	41	10

Note: Teachers' responses from UK (20.6., 21.6.), EE (3.7.), CH (10.7.), GR (30.7., 3.8.) and students' responses from UK (1.7.).

The results show that the current tabs are sufficient representation of the inquiry cycle phases. 29 teachers supported the idea because it shows a linear sequence of inquiry cycle phases. As it is a common way of navigation in the Internet, the students would be familiar with it and find it more understandable than the circle representation.

The circle representation was preferred by 13 teachers for its modern look. Fifteen teachers proposed to enhance the circle look by adding different colours to each phase. Four teachers suggested moving the circle to the left or centre to be more noticeable. One teacher suggested using colour scheme that helps to distinguish covered, current and remaining phases of the inquiry cycle.

Four teachers pointed out that the selection between tabs and circle could be dependent on the target group, where circle would be better for younger and tabs for older students. Two teachers asked for both alternatives simultaneously.

When 28 primary school students were asked the same question, two thirds preferred tabs to circle. Individual students thought that the tabs would be clearer for navigation, but take more space than the circle; the circle was viewed as more *"kid friendly"*; the size of the circle was commented as it was too small to read; and finally the students also missed the start of the circle.

- **RQ2:** Is there a preferred sequence through the phases or should students be able to move freely between phases?
- **A2:** No, there is no other preferred sequence; the existing order of phases is accepted.

Data source: Layered Elaboration and Virtual Stickies

The results imply keeping the existing linear sequence of the inquiry cycle phases, because the teachers and students evaluating the current mock-ups did not indicate any need to modify the order of the tabs. Only two students found the activity *"too long"* in the Investigation phase and a teacher warned that *"to do all the steps of IBSE [inquiry based science education] on the computer at one time might be too much"*. Hence, the lab assignment can be split into several classroom sessions and the students should be given the opportunity to resume where they have left off upon returning.

- **RQ3:** Should students be able to start free experimenting without an orientation?
- **A3:** No, the orientation phase is deemed important.

Data source: Layered Elaboration and Virtual Stickies

Introducing the background information in the Orientation phase was found of great importance according to ten teachers' comments and should be a part of the learning process. The teachers found the current implementation of Orientation and Conceptualization phases motivating and proposed a number of improvements as described in Section 4.2.3.9. Rather than extending the introduction, two teachers evaluating the Conservation of Momentum activity found it necessary to explain additional pre-requisite knowledge in the class, yet neither of them intended to skip the orientation.

- **RQ4:** Should all inquiry phases be available or should some of them be greyed out?
- **A4:** All the inquiry phases should be available all the time.

Data source: Layered Elaboration and Virtual Stickies

The teachers and students evaluated all inquiry cycle phases and there were no comments indicating the need to remove any part of the tabs.

- **RQ5:** Should navigation between phases only be possible through the tabs?
- **A5:** Yes, navigation between phases should be done with the tabs given.

Data source: Layered Elaboration and Virtual Stickies

The current form of navigation using the tabs and "Next"/"Back" buttons was well accepted by the teachers and students evaluating the mock-ups and they provided many suggestions for navigation improvement. One teacher and two students proposed that "Next" and "Back" buttons can be moved to the bottom of the page to avoid scrolling up once reaching the end of a page. Two other students valued the buttons, but one thought a sub-phase (e.g., Investigation 2/4) can be missed if the labels (e.g., "1/4") are not seen. This concern was also shared by one secondary school teacher who would prefer *"easy to use tabs"*. Also one primary student would expect the "Next" button in the last sub-phase of the Conceptualization phase in Buoyancy lab. Finally a secondary student would like the tabs to be colourful and a primary student asked for the tabs to stand out more.

4.2.3.2 Discussion phase

- ▪ ***RQ6:*** Should students do a reflection per phase or perform all reflection at the end? Same question refers to reporting?
- ▪ ***A6:*** While no notable difference in preference among the teachers is found, the MyReport tool seems a more desirable option. In contrast, the students unanimously prefer Chat.

Data source: Selecting Design Options - MyReport vs. Chat vs. Classroom

Printout 9 - discussion captured in **one** place and as **one** phase

Printout 10 - discussion **throughout** the phases as **chat**

Printout 11 – discussion in the class
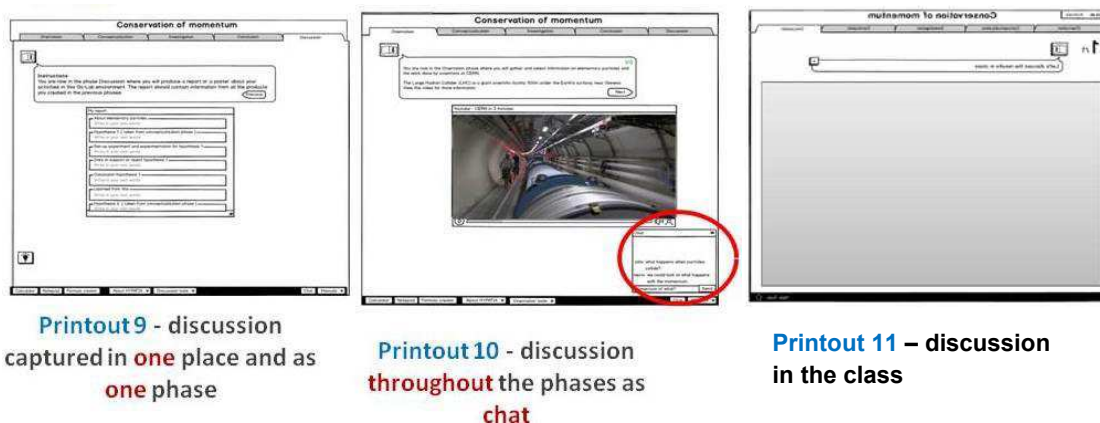
Discussion	Teachers	Students
Using MyReport tool at the end	**56**	0
Using Chat in all the phases	46	**28**
Classroom at the end	43	0

Note: Teachers' responses from UK (20.6., 21.6.), EE (3.7.), CH (10.7.), GR (30.7., 3.8.) and students' responses from UK (1.7.).

The results show that most teachers preferred MyReport template for the Discussion phase. 13 teachers appreciated that the template could serve as guidance for students and four other teachers saw the value of using it as a summary for assessing the student work. But the chat and classroom discussion also received significant support by the teachers, who believed that a combined use of these two or even three options could work better than relying on only one of them. While the above table lists the number of the votes each option received, some teachers voted for a combination of two. (Specifically, all three options combined were preferred by eleven teachers; nine would like to use a combination of the continuously opened chat window and MyReport at the end, while five would prefer MyReport followed by a classroom discussion; and finally nine teachers would prefer a chat combined with a classroom discussion.)

The teachers evaluating the design options offered several suggestions on the forms of discussion. For example, a system-generated activity report based on students' performances in the earlier steps that can be a useful solution for less able groups. The comments in MyReport could be expanded out to a forum discussion (e.g., a Facebook group) that would encourage students to ask questions. The teachers also proposed chat monitoring.

Data source: Layered Elaboration and Virtual Stickies

More ideas extending the forms of discussion were offered by the FAULKES/Interacting Galaxies mockup evaluation. An online discussion forum or blog to discuss the topics with other students or teachers within their school community was proposed by a teacher and three students. A group of teachers evaluating the HYPATIA/Conservation of Momentum mockup proposed that a presentation such as a poster could be an attractive alternative for reporting activities. Two teachers proposed that the MyReport tool should be enhanced by a printing function, and that

students should be enabled to store the report in their folder. A secondary student suggested having a "submit conclusion" button.

Five teachers evaluating HYPATIA//Conservation of Momentum showed uncertainty about the chat functionality. They recommended including chat instructions with characteristics such as response-time (real-time/ asynchronous) and participants (students/teachers/scientist/all; local/remote). Several particular directions in which chat could be used were envisioned by four teachers including students' discussion within a working group; discussions between classes from different countries; and students in need of help directly asking the teacher a question ("chat box labelled S.O.S. or Teacher"). Two teachers expressed concern about the tool efficiency and susceptibility to abuse ("could be open to abuse where some students would just have a chat and go off the task") and three teachers did not favour using chat at all. Finally some solutions to the chat abuse emerged from teachers' comments. The first option would be a moderated discussion, because chat without a moderator can deviate from the subject. Alternatively, the teachers asked for the functionality to switch off the chat or to divide the class into groups, chatting with group members is supported but not with non-group members. Nevertheless, only one student shared the concern that chat "may be used inappropriately" and most students liked the idea of chat.

The implication from the above analysis results is that the MyReport template should be used for reflection and reporting in the Discussion phase. It would be desirable to include the chat functionality because of the strong support, especially among students, but the implementation should consider several concerns raised by teachers and students.

4.2.3.3 Window layout

- ▪ *RQ7:* Should all the information be presented in one scrollable window (or split between windows)?
- ▪ *A7:* Teachers are equivocal between the two options whereas student prefer the single-page scrolling

Data source: Selecting Design Options - Single-page scrolling vs. Split-page with back-next buttons
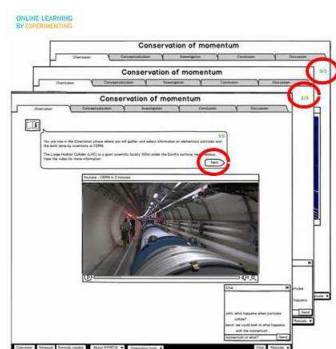
Printout 5 – Inquiry cycle phase split over three screens
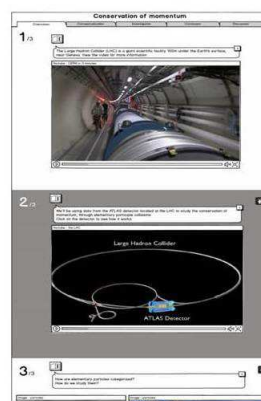
Printout 6 – Inquiry cycle phase on a single page that can be scrolled down

Inquiry cycle navigation	Teachers	Students
Single-page	52	**17**
Split page with back-next buttons	**59**	9

Note: Teachers' responses from UK (20.6., 21.6.), EE (3.7.), CH (10.7.), GR (30.7., 3.8.) and students' responses from UK (1.7.).

The opinions of teachers and students were not conclusive on the selection between the single or split-page window layouts. The numbers of the teacher participants with opposite preferences were almost equal. In contrast, more students (65%) preferred the single-page option.

The inquiry phase split over several pages was preferred by 59 teachers, because of the familiar "back" and "forward" navigation format known from typical web activities. Some teachers supported this alternative because it allows breaking complex ideas into smaller segments on which students can focus. It can also prevent students from overseeing future steps or from getting lost in a large, complex page represented by the second alternative. However, some teachers pointed out the need to highlight the sub-phases to prevent students from missing them. Several teachers also found this alternative more adaptable to different screen sizes. In contrast, thirteen teachers found the inquiry phase on a single page better organized and easier to use, because the content is divided into logical components corresponding to the inquiry phases. This allows students to quickly gain an overview of the phase content and helps to avoid losing students' attention by additional navigation (e.g., buttons). However, the scrolling needs to be explained to the students. Nine teaches found this option better for certain interaction methods and devices such as tablets. Thirteen teachers would prefer to have both alternatives, enjoying the freedom to choose and arguing that students can be accustomed to either layout quite easily.

Furthermore, 17 students voted their preference for the tabs and navigation using the "Next" and "Back" buttons, because they were used to this kind of navigation and some found it faster. On the other hand, scrolling down seems easier and quicker for nine students.

- ▪ *RQ8:* Should we make more separate windows to avoid information overload?
- ▪ *A8*: Yes, providing more separate windows for information presentation is deemed desirable.

Data source: Layered Elaboration and Virtual Stickies

The teachers required more windows and layout modifications of the existing online lab activities as described by the following examples. Eight teachers and a secondary school student provided new insight into the organization of Interacting Galaxies (IG) and Conservation of momentum (CoM) mockups. They suggested that tools could be made larger or located on a separate page (Conceptualization, CoM); images that may contain further explanation and spread over a number of screens (Orientation, Investigation 2/4 CoM) or they can be on a single page but numbered to assist student's navigation (Investigation 2/4, CoM); and finally some tools should follow the logical order of the learning process, for example, to swap Concept Map and Hypothesis tool (Orientation, CoM). An optimal window layout was indicated by a secondary school teacher (Orientation, IG), considering it the appropriate amount of text for students of different age groups, namely, 12-14 years old as a group and 15-16 as another. Also, the window layout should be carefully balanced with the length of the activity in order to have an appropriate duration for the respective students.

4.2.3.4 Toolbar location

- ▪ *RQ9:* Where is the best location of the toolbar?
- ▪ *A9:* Both teachers and students prefer the toolbar to be located at the bottom of the screen; teachers prefer the tools to be hidden (or closed) when they are not in use.

Data source: Selecting Design Options - Top vs. Bottom vs. Side and Closed vs. Opened

Printout 12 – toolbar at the bottom (tools closed)

Printout 13 – toolbar at the bottom (tools opened)
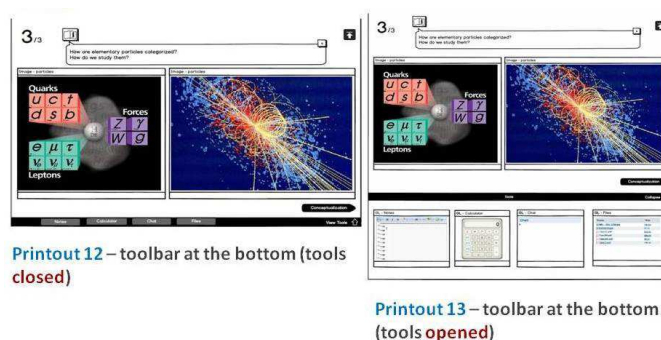
Toolbar location and tools representation		Teachers	Students
Location	*Bottom*	**49**	**23**
	Top	9	2
	Side	10	0
Tools	*Closed*	**63**	0
	Opened	32	0

Note: Teachers' responses from UK (20.6., 21.6.), EE (3.7.), CH (10.7.), GR (30.7., 3.8.) and students' responses from UK (1.7.).

The data collected indicate that providing a closed toolbar located at the bottom of the screen was the favourite design option for both teachers and students. Specifically, the closed toolbar alternative was attractive for thirteen teachers because it allows focusing students' attention on the learning content; avoids cluttering the user interface; and it is a familiar toolbar representation for students. Seven teachers considered the opened alternative as a means of providing students with necessary information simultaneously (i.e., content and tools).

The teachers proposed several toolbar modifications in addition to the static arrangement presented in the design options. For example 15 teachers asked for the possibility to open and close the toolbar window; 21 teachers would let the students open, close and position individual tool windows on the screen; and four teachers pointed out that the form of the toolbar (opened/closed) can be dependent on the device screen size. If the content of the screen would exceed the visible window area, four teachers suggested using a floating toolbar. Having all tools available throughout the phases of inquiry cycle instead of a phase-specific selection was preferred by the teachers (4:1) and students (15:11).

Four teachers evaluating HYPATIA/Conservation of Momentum mockup proposed to highlight and better organize the tools, for example, by moving Formula creator in the Notepad, highlighting the chat and making clear what each button represents. Integrating the tools with the navigation bar and thus creating a menu structure similar to the MS Office tools pane (i.e., selecting a tab opens the tools available for this phase) was an interesting suggestion.

4.2.3.5 Working offline

▪ *RQ10:* Should some phases be done offline?
▪ *A10:* Basically no phases should be done offline, but in some circumstances such an option could be useful.

Data source: Layered Elaboration and Virtual Stickies

The teachers' and students' comments did not indicate any particular phase that should be carried out offline. Rather than requesting an entire phase to be substituted by an offline version, the teachers reported several examples of the activities within a phase that can be carried out offline. Two teachers found it necessary to explain in class pre-requisite knowledge that complements the information in Orientation and Conceptualization of the Conservation of Momentum learning

activities. Carrying out discussion or asking students to present their results in class would be preferred by the participants of the workshop in Cyprus, who also argued for the need of an offline option of the entire online lab, because not every school has the Internet access in every classroom.

4.2.3.6 Lab description

▪ **RQ11:** Is the lab description at the start sufficiently informative?
▪ **A11:** Yes, the lab description is informative, but some modification would further enhance it.

Data source: Layered Elaboration and Virtual Stickies

The lab description was considered sufficient, although some parameters describing the Interacting Galaxies and Conservation of momentum activities should be reviewed. Some teachers proposed new features that could be introduced in the description page.

Specifically, seven secondary school teachers offered new parameters, including *required skills, group or individual activity, link to the national curriculum* and *technical requirements* (e.g., Java, Flash, browser compatibility). The parameters in the Details section motivated five groups of teachers to revise the *age range, teaching time* and *difficulty level* (e.g., *"age range from 17"* or *"difficulty - high"*) for the Conservation of Momentum activity and one teacher wondered if the Interacting Galaxies activity is suitable for the proposed wide age-range of students. Three teachers did not understand some parameters or terms in this section (e.g., *Structure, Interactivity level, Difficulty; didactic*, *linear*), two teachers asked for teaching time in minutes instead of hours and one teacher would prefer the have "the objectives written using Blooms Taxonomy (understand, describe, explain, etc.). Finally several comments regarding the Educational Objectives were contradictory. For example, two teachers considered them extensive, while another two would prefer to have more information and in different order. One teacher would separate three kinds of learning goals (concept, attitude and science skills) and another would exclude the conversion to degrees of angle, because students should already know how to do it.

▪ **RQ12:** How much should the guidance be adapted to age level or student competence?
▪ **A12**: In general guidance adaptation is regarded as important with the language issue being most critical one.

> *Note:* Also the related question "Is the level of support the same for all students, domains, topics, or should this be adaptable (e.g., through fading)?" from the Pedagogical research questions is answered in this section.

Data source: Layered Elaboration and Virtual Stickies

A number of comments collected from Layered Elaboration and Virtual Stickies revealed that the teachers recognized the need of adapting guidance to the students' ages and competence levels. Of particular interest are the terminology and language as well as the form of instructions, which have been pointed out by many teachers whose comments are summarized in the following subsections.

Terminology and language

The terminology issue of the Go-Lab mockups has been pointed out by all secondary school teachers. The current language level would pose difficulties for the students and it needs to be adapted. For example, the terms in the FAULKES/Interacting Galaxies activity (e.g., *"orientation", "conceptualization", "heuristics", "peri", "tidal interaction", "interferences", "morphologies"*, etc.) were found too complex for the students of the age range of 11-16, because the terms are not part of the scientific methodology used at schools. Seven teachers evaluating Interacting Galaxies and

Conservation of Momentum activities suggested more straightforward and accessible language for the students, for example by following replacements:

- o Orientation **<>** Introduction, Setting the scene, Background reading or Background research
- o Conceptualization **<>** Aim or Making a hypothesis
- o Orientation -> Conceptualization -> … Discussion **<>** Step 1 -> Step 2
- o Heuristics **<>** Note, Subscript or Tips

Also three teachers proposed to include a glossary and the individual teachers' suggestions included: allowing a teacher to review the lab content; avoiding culture dependent terminology (e.g., concept map vs. mind map); and *"linking the Hypothesis tool into 'How Science Works' terminology including 'Independent variable' and 'Dependent variable'"*.

The teachers' concerns were confirmed by primary and secondary school students. About 90% of the primary school children had great difficulties with the terminology of the Buoyancy activity, in particular in the Orientation and Conceptualization phases. Also about 60% secondary school students found the terminology of the Interacting Galaxies activity complicated; they struggled with the language complexity in Orientation, Investigation and Conclusion phases. Consequently, the students asked for clear, informal and child-friendly language and the terms description, for example, in the form of a glossary or an explanation displayed by a mouse click or hover-over.

Instructions

The teachers and students evaluating three online lab activities (Conservation of Momentum – CoM, Interacting Galaxies – IG and Buoyancy – BU) identified examples of instructions that should be adapted in terms of complexity, volume and consistency for better suitability to the students' age or level of competence. Their comments regarding each activity are summarized as follows:

The complexity of instructions has been pointed out by most participants. For example the learning content presented on the images in Orientation (3/3), Conceptualization and Investigation (1/4, 2/4) phases (CoM) was thought to require quite a high level of pre-existing knowledge in students according to eleven teachers, and the guidance in the Conceptualization, Investigation (2/4, 4/4) and Discussion (IG) was considered by four teachers to be exceeding the appropriate complexity. The points raised by the teachers were supported by the opinion of eight secondary school students asking for more explanation in simple language on the use of tools in the Investigation phase (IG), and two other students found the use of the tools in Conclusion and Discussion (IG) unclear. They would prefer more instructions and examples of conclusion. Finally a descriptive example of the instructions complexity was given by a secondary student and supported by a teacher in the Conceptualization phase: "*The questions don't seem to link in with the overall subject of the page. They should really aid in writing a hypothesis rather than asking general questions that don't seem to formulate the basis of the hypothesis.*" About 80% of the primary students also asked for modification of the existing instructions in the Buoyancy mock-ups. They would prefer more clear and shorter instructions in the Orientation phase (1/2, 2/2; BU) and more detailed and easy to understand guidance in Investigation (4/5; BU).

The volume of instructions was found excessive only in one case where a teacher thought the guidance in the Conceptualization phase (IG) was *"a bit wordy for Key Stage 2"* (aged 8-11). The opposite view had six teachers in the Investigation (4/4) and Discussion phases (IG) and four teachers in the Conceptualization and Investigation (1/4) phases (CoM) who regarded the instructions as insufficient for the target group of students. A general suggestion to keep the instructions consistent in the lab was given by five teachers, pointing out the need to use matching

symbols between corresponding physical quantities in tools and instructions (Investigation 4/4) and for colour scheme consistency in the Hypatia tool displayed across several images (Investigation 1/4).

The main solutions to the instructions complexity include giving teacher explanation in class, providing a hyperlink to a site with necessary description or including extended instructions, descriptive titles, legend or a video in the lab.

- ▪ *RQ13:* Are the general tools adequate or is something missing or useless? For example, a (dedicated) notebook for the students (e.g., to write down their answers to specific questions)?
- ▪ *A13:* The opinions are mixed, ranging from appreciating the scaffolds provided in the mockups to finding them difficult to understand; additional tools such as sketchpad are proposed.

Data source: Layered Elaboration and Virtual Stickies

Considering the instructional scaffolding tools adequacy, seven secondary school teachers recommended the tools adaptation to student's age and competence level. For example the Hypothesis tool presented in Interacting Galaxies activity was found useful for younger students (aged 14–16) by two teachers, but one asked for further differentiation of the support levels to the age range. Moreover three teachers pointed out the complexity of Galaxy Crash Simulator, given the age range of the target students group. They suggested the simulator adaptation by using very clear and simple variables or modifying only one variable at a time. Also three teachers considered the low ability students, who would not understand the questions in My Conclusion tool. They proposed more structured conclusion or using multiple choices for answers offered by the tool. Finally an adaptation of the My Report tool was suggested by a teacher, who would consider consulting exam board and teachers to construct the tool with content that is expected by the school for the target group of students.

A prevailing opinion among the teachers and students was that the scaffolds are helpful and motivating. Eight out of ten secondary school teachers evaluating Interacting Galaxies activity gave positive feedback and highlighted the Hypothesis, Go-Lab notes and MyReport tools. Also two secondary school teachers evaluating the Conservation of Momentum activity considered Notepad a good idea. Finally five secondary school students approved Calculator, Chat, Go-Lab notes, Hypothesis and Drawing tool as very helpful tools.

According to the teachers and students' comments, there is a room for improvement of some features in the presented tools. Frequently cited modifications regarded the size and position of a tool. Larger or resizable Concept map and Go-Lab notes would be welcomed by three teachers and around twenty secondary school students. Both primary and secondary school students would also change the size and make the content more readable in the toolbar, Calculator and Galaxy Crash Simulator. The teachers and students further agreed on the need of additional instructions on using tools. It can be in the form of hover over descriptions of buttons as proposed by two teachers and five students for the SalsaJ, Drawing tool and Hypothesis tool or as more friendly prompts suggested for MyConclusion and MyReports tools by six teachers and seven students. Finally two secondary school teachers and a student proposed to link the Go-Lab notes with the guiding questions in instructions besides using it as an individual notepad. Unfortunately nine primary school students could not quite understand the Concept Map, Experiment Design and My Report tools in the non-interactive mock-up. They asked for more child-friendly versions and for more explanation of the interface objects (e.g., Aquarium laboratory preview, Objects).

- *RQ14:* Should students be able to make changes in a scaffold from a previous phase or should this be restricted to a specific phase and should all scaffolds be available in all phases (bottom tab)?
- *A14:* Tools should be available in all phases and activated on demand.

Four teachers evaluating different activities agreed that the Hypothesis tool should be present also in the Investigation and Conclusion phase. Then three teachers and one student would prefer Go-Lab notes available continuously in all phases to store information. Fifteen teachers also supported the idea of selecting a tool whenever the students need it.

4.2.3.7   New tools

- *RQ15:* Are there forms of guidance/scaffolds that are currently missing?
- *A15:* Yes, for example, a progress monitoring tool for teachers and audio tools for students.

Data source: Layered Elaboration and Virtual Stickies

A particular secondary school teacher was interested in monitoring the students' progress and proposed to include a tool that would be *"monitoring which tasks have been completed"*. *"If a student has skipped a certain stage then a tool should exist that prevents students from moving on to the next stage before completion"* (Similarly another secondary school teacher asked if students *"need to complete notepad to proceed"* in the Orientation phase.) He then proposed *"time monitoring with option to add more time to time limit"* and the out-of-class activity saying *"students should be able to complete at home and teachers should be able to monitor this"*. Another teacher was interested in the video application, suggesting that it could allow *"to select segments [of the video] so students can select specific parts of the clip to watch"*. Also the chat enhanced with Clicker[2] scaffold was proposed by another secondary school teacher. Finally, a "My Idea" scaffold was proposed by fifteen teachers to allow students to express alternative investigation plans.

Some creative students proposed several tools that can facilitate the use and keep student focus on a specific activity of an online lab. The activity-specific tools include a student's proposal *"small scale images to directly compare originals/edited versions to see if it's worth changing"* in Interacting Galaxies activity and three students agreed on including *"gallery from captured images"*. Some students suggested a *"music player"* and *"speaker button"* for the instructions and a *"grammar check"* for entertainment and accessibility purposes. Two students proposed a *"finish button"* as an option to publish their report at the end of the activity.

4.2.3.8   General online lab remarks

The participants evaluating the online labs provided some comments unrelated to the previous categories. They are summarized here. The PD workshop report from Cyprus voiced an opinion on the selection of online labs. For example the use of the Aquarium Web Lab/ Buoyancy activity may be questionable since it could be very easy to carry out in the classroom. The teachers proposed to use other examples which are difficult to carry out in the classroom (e.g., nuclear physics, radioactivity, zero gravity, serial and parallel circuits etc.). The majority of the students and teachers involved in the mockups evaluation asked for a child-friendly environment. The most common requirement was to provide more colourful, playful and attractive environment for the students. The Estonian PD workshop listed a set of topics that were popular among the teachers and could be an interesting topic for online labs development:

- Using a computer simulation to introduce the principles of relativistic physics.

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[2] http://www.cricksoft.com/uk/products/tools/clicker/home.aspx

- Investigating the oscillation of a mathematical pendulum and spring pendulum (demonstrations and computer simulations).
- Investigating the working principles and applications of transformers and oscillatory circuits (demonstration or computer models).
- Investigating using models of the atom, the fundamentals of quantum mechanics (computer simulations).
- Investigating issues of radioactivity, ionising radiation and radiation safety (computer simulations).
- Investigating the solar system and the structure of the universe (computer simulations).
- Investigating two electric pendulums (electrified foil cylinders hanging on a thread) or the same using computer simulation using the laws of electrostatics.
- Using a laser to explore the diffraction picture obtained from a single slit, double slit and single hair and finding the inverse proportionality between the width of the slit and width of the diffraction picture (practical work or computer simulation).
- Identifying patterns in planet movement (with the help of computer simulations).
- Investigating nuclear technology, the mechanisms of nuclear weapons and radiation safety (educational video).

4.2.3.9 Feedback for the designers

Data source: Postcard (Section 4.2.2.4)

The teachers' feedback was rather consistent in terms of their appreciation towards the provision of a centralized database of online labs enhanced with the inquiry-based learning approach. Nonetheless, they pointed out the need to give greater consideration about the heterogeneity of student abilities by adapting the language and task set. This is especially relevant to Go-Lab as it aims to support students of a large age range (10-18). In addition, teachers expressed their wish for experiments on specific topics, for example, climate and environment with physics.

Also, the students mostly agreed on the positive and negative aspects of online labs. They all regarded using such labs as a good idea, because it allows carrying out experiments that one cannot do in the classroom. Most students found the lab well-structured with the clear step-by-step process providing easy access to each section. Although instructed that what was presented in the workshop was an early prototype, they all proposed more aesthetically pleasing and exciting interface to encourage people to want to learn.

The primary school children selected the chat tool as the most interesting aspect of the Aquarium online lab, followed by the positive comments on the online labs idea, easy to use structure and attractive content (e.g., images, videos). Almost all students considered the language too complicated with too many confusing words and would prefer to have more description on what words mean. In addition, they would like to see more child-friendly environment including the use of colours and pictures.

4.2.4 Reflection on PD workshops

In the period of four months, more than a hundred teachers and students from primary and secondary schools from several countries took part in the PD workshops. The hands-on activities enabled participants to have direct experience with the mock-ups and thus provide their comments and improvement suggestions. The PD protocol was made flexible in order to satisfy the different personal (e.g., limited prior experience with online labs) and organizational constraints to be dealt with by the participants (e.g., slow internet connectivity, room size). The nine PD workshops have led to comprehensive data and insightful results, which could answer some of the research questions pertaining to the pedagogical frameworks of Go-Lab learning spaces and also generate the requirements for the future development of the Go-Lab Portal.

Nonetheless, the organizational constraints in terms of limited time (short slots of two hours) and undesirable infrastructure (no or poor internet connectivity) hindered us from launching a whole day PD workshop. As certain basic information about online labs (especially for those who have no related prior experience), the Go-Lab project and the inquiry learning cycle is critical for

participants to give relevant feedback, a longer session would be ideal to build up this ground for discussion. Above all, the short two- and three-hour PD workshop sessions proved valuable for gathering a good amount of useful data.

5   Requirements

5.1 Overview

To derive requirements from the feedback of PD participants, all comments given during the PD workshops (Section 3.2.2) have been examined. The requirements so identified have been clustered into *general requirements*, *requirements for tools*, and *specific requirements for single screens* where they were mentioned. Two parameters - *obligation* and *impact index* – for requirements prioritization have been identified and their values have been assigned based on the discussions of the researchers involved.

To ensure the readability of this document, all "must have" and "the more important should have" requirements have been presented in its main body - Table **R1** to Table **R10** ("R" stands for requirements) whereas all "nice to have" and "less important should have" requirements have been put in Table **R11** to **R36** (see *Appendix B: Less Important Requirements)*.

Note that one very broad, high-level requirement – *Go-Lab portal must be child-friendly* - does not fit into any of the requirements categories identified. However, this specific requirement is deemed important and supported by some more specific lower-level ones. As (young) students are one of the main target groups of Go-Lab, it is very important to create an environment which they perceive as friendly in order to encourage them to use it. Although that issue was raised by several participants (mainly students from a primary school) on every aspect of the portal (language, layout, etc.) on different screens, it was rarely specified in more detail what exactly in the current version is not child-friendly or could be done to create a child-friendly portal. Nevertheless, other requirements suggest what changes could be done to achieve this goal (e.g., speaking the users language).

5.2 Structure of Requirements Tables

In this section, we explain the implication of individual columns of a requirement table.

*Code***:** The requirements are presented in tables, which contain additional information besides the actual requirement. The first column is "Code" (e.g., PR-Gen-FR001), which is used as an identifier for referencing this requirement from within this or from other documents. The first two letters are either *PR* for *pedagogical requirement* or *TR* for *technical requirement*. The next bit is an abbreviation of the target of the requirement, e.g., "Gen" for a general requirement, "NewT" for a new tool proposed or "M3-Buo" for a requirement derived from a comment on mockup 3 of the Buoyancy lab. The last bit contains *FR* for feature request, followed by a three-digit sequence number. During the process of creating this document, some of the requirements have been deleted or merged into other requirements, thus some of the numbers are missing.

*Obligation***:** The next column is obligation. To help the development team to assess the different requirements, they have been categorized as a *must have*, *should have* or *nice to have*. This obligation is derived from the role of the person(s) who has stated the comment(s) resulting in this requirement (teachers having more expert knowledge and are thus rated higher than students), as well as based on the number of times it has been stated (assuming the positive relationship between frequency and importance) and on the knowledge of the researchers involved in analysing the requirement. The requirements are ordered by obligation.

Impact Index: The column impact index shows how much of the portal would be affected by implementing this requirement. This could give developers an indication on the amount of time and effort which might be needed to implement this requirement and to what extent the users would

notice the changes caused by this requirement. The value of the impact index ranges 1 to 5 with the following implications:

1   very low: only a small part of an interface element / tool used on one screen;
2   low: only one interface element / tool used on one screen;
3   medium: several interface elements / tools on the same screen or changes on one element / tool affecting the whole screen [e.g., making something full screen]);
4   high: one or several interface elements / tools used on several screens
5   very high: influence on the whole portal.

Description: The next column is description, which holds the requirement itself.

Example: To give the reader some background information or the opportunity to have a look at the original participant comment, an example of evidence for the requirement is given in the example column. To retrieve the original comment from the data gathered, the data unit identifier is given together with a transcription of the comment. Additional information has been added in square brackets during transcription to point out the target of the comment and make the transcription more understandable (e.g., MyReport could include more information on what to write). How the data unit identifier can be used to find and have a look at the original comment is described in *Appendix C: How to retrieve more detailed information*.

Reasoning for obligation: For all requirements in the main document the reasoning for the obligation assigned is given in this column. For most of the requirements in the appendix this column has been removed, because most of them are very specific or have been mentioned only once and are therefore only nice to have.

Frequency (Freq.): The number of comments which were associated with each requirement is given in the frequency column. This information has already been used to determine the obligation but could also be a helpful indicator for the developers when deciding on the requirements to implement (first).

Additional information: Some of the tables have a column for additional information about the requirements. These are most of the times references to similar requirements.
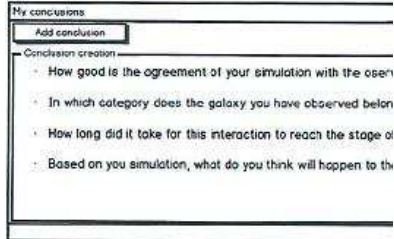
5.3 *Requirements Identified for the Pedagogical Team (WP1)*

This sections presents all requirements identified, which are *not* addressing the technical implementation of the Go-Lab portal (functionality presented in the prototype) but its content. These requirements can therefore not be implemented by the developers (alone). The pedagogical experts first need to come up with a solution, which can then be implemented. Additional requirements (e.g., "Students could be able to complete labs at home.") to the ones listed in Table R1, which are interesting but less important, can be found in Table R11.

Table R1. Pedagogical Requirements

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
PR-Gen-FR001	Must have	5	Go-Lab portal must speak the users' language to enable the students and teachers to understand meaning of interactive elements, instructions and (learning) content. Unfamiliar terms must be explained, e.g., using a glossary (see tools TR-NewT-FR003 and TR-NewT-FR008 proposed.)	SF_2013_06_20_m0_p10 (More age appropriate language.) SCP_2013_07_01_m1_g2_p2 (Make the language more child friendly) CERN_2013_07_10_m0_g10_p3 (Write in student language, change language) CERN_2013_07_10_m1_test1 ([comment:] English terminology is too difficult for children who do not use English as a first language. e.g., "get acquainted" "adding")	Pedagogical requirement which was mentioned the most by all participants. Students and teachers need to understand the portal to benefit from it.	74	Specific examples: "The use of this language [conceptualization phase] will confuse students, call them step 1 -> step 2 etc." "The word "variable" would be more useful to pupils than the word "parameter"." "The prompts could be more user friendly. E.g., What do you know about how galaxies interact? What I expected to find out? What I did to test this? How did the results back up or disagree with my hypothesis? What I learned from this?" "The words Orientation and Conceptualization are not used in our scientific method. Something like Background Reading or Background Research and "aim" or "making a hypothesis" may be more helpful" I'm not sure what you mean by "orientation" and "conceptualization" so I'm sure the students will not understand. Needs to be in pupil speak e.g., introduction, setting the scene?
PR-Gen-FR002	Must have	4	The amount of information on each page and in a whole lab must not exceed the level	SF_2013_06_20_m2_p10 (This is a bit wordy for Key Stage 2. Would these be different for different ages?) SF_2013_06_20_m5_p5 (This	Mentioned by students and teachers alike. If this	9	This requirement is a more specific requirement supporting the one that "Go-Lab portal must be child-friendly."

				that target group can handle.	feels like way too many pages already…) CERN_2013_07_10_m4_g8_p2 (Sequence the questions so that it doesn't appear so word dense.) CERN_2013_07_10_m4_g8_p2 (To do all the steps of IBSE [inquiry based science education] on the computer at one time might be too much.)	requirement is not met, Go-Lab portal cannot be used successfully.		
PR-Gen-FR003	Must have	4	Learning content needs to be comprehensive enough for all students of the target group. If the target group is wide (e.g., age range or skills) adapting the content might be an option.	SF_2013_06_20_m5_p6 (Why did they vary it? ["astronomers varied" in Info bubble text])	Confusion about the existing content has been expressed on several occurrences. If this requirement is not fulfilled, learning with the portal would be really hard or even impossible.	6	If clashing with PR-Gen-FR002 this has priority.
PR-Gen-FR004	Must have	4	Instructions need to be detailed enough, clear and understandable, so that students always know what to do (next) to achieve their goal. They could give examples while describing what to do.	SF_2013_06_20_m9_p10 ([My report] could include more information on what to write) SF_2013_06_20_m2_p6 (Example? [Info bubble text])	Pedagogical requirement which was mentioned second most. Students cannot work with the portal, if they do not know what to do.	46	If clashing with PR-Gen-FR002 this has priority.
PR-Gen-FR005	Must have	5	Content of Go-Lab platform needs to correspond with the learning needs at schools and government	SF_2013_06_20_m9_p10 (could be worth consulting exam board and teachers to help fill [My report] with what is expected at school)	Although mentioned by only one participant, this is a very important	1	Supports PR-Gen-FR003

			regulations regarding the curriculum.		requirement for the use of Go-Lab at British schools.		
TR-M0-Gal-FR001	Must have	1	The lab description has to correspond to the lab content (e.g., age range).	SF_2013_06_20_m0_p10 (Does this [Age Range] mean it is suitable for all. Could different groups do different activities?) CERN_2013_07_10_m1_test1 ([comment:] Overall in our opinion the level is slightly too high for some 15/16 year old students.)	The information on the labs to needs to be appropriate for the teachers to make the right choices.	1	
TR-M2-Gal-FR006	Should have	1	Instead of drop-down boxes to choose predefined options from the students should be allowed to create their own hypotheses in the "GL – Construction of Hypothesis" tool.	SF_2013_06_20_m2_p5 (Why drop down boxes [Hypothesis tool]? Can you not construct your own instead of choosing from a list?)	Depending on the age and level of students they should have the freedom to formulate their own hypotheses.	2	
TR-M7-Gal-FR001	Should have	1	Students should be able to choose or type (depending on their ability) answers to the questions in "My conclusions" directly underneath each question.	SF_2013_06_20_m7_p10 (Ability for children to answer under questions, like a writing frame [My conclusions])	Depending on the skills and age level of the students, some more guidance might be needed when drawing conclusions.	3	

5.4 Requirements Identified for the Technical Team (WP4)

5.4.1 General requirements

This section presents all requirements identified, which address the technical implementation of the Go-Lab portal (functionality presented in the prototype). These requirements can serve as a guideline for the rework and further prototype implementation by the development team.

It starts with general requirements for the whole prototype in Table R2 and continues with more specific requirements for single tools (Table R3 to Table R5) and screens (Table R6 to Table R10). Additionally, less important requirements (e.g., "An option to switch between different languages would be nice." Or "Tabs for navigation could be at the bottom as well as on the top of the page") can be found in Table R12 to Table R36 (see *Appendix B: Less Important Requirements*)

Table R2. General Technical Requirements

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-Gen-FR001	Must have	5	Some kind of direct short help (e.g., tooltips) needs to be offered explaining all functionality.	SF_2013_06_20_m4_p10 (What do these [SalsaJ, zoom buttons] do?)	If functionality is not clear to the user, he cannot interact with the system.	11	
TR-Gen-FR004	Must have	5	Design of Go-Lab portal needs to be visually appealing to the students and teachers (e.g., by using colours and pictures).	SF_2013_06_20_m1_p1 (Needs more pictures) (Needs more colour) CERN_2013_07_10_m0_g6_p2 (Image should be in colour at the very least and preferably a moving image.)	(Technical) requirement that was mentioned the most. An appealing portal will encourage the students to work with it.	80	
TR-Gen-FR006	Must have	5	Font must be large and clear enough with sufficient spacing to be easily readable on the screen.	SF_2013_06_20_m1_p6 (larger font) CERN_2013_07_10_m0_g6_p2 (Font size needs to be larger.) VOLOS_2013_08_03_m2_p9 (needs a larger font)	Mentioned by a lot of participants and necessary to work with the portal.	33	
TR-Gen-FR014	Must have	4	Go-Lab portal must save changes on pages while the user works with a lab.	SF_2013_06_20_m5_p6 (And save current page for la[t]ter.)	Auto-save for all input is necessary so the student does not lose any of his or her work.	1	
TR-Gen-FR025	Must have	4	Tools included in pages need to be large enough to read their content and interact with them properly.	e.g., CERN_2013_07_10_m4_g7_p3 ([of Concept map] picture too small [N.B. participants refers to tools as 'pictures']) CERN_2013_07_10_m5_test8 (In the Live version, is the Concept Map resizeable? In this version it is too small to be easily read.) VOLOS_2013_08_03_m4_p9 ([line to "My concept map"] larger?)	If the tools are too small working with them properly is not possible.		This requirement has been derived from comments about the readability of tool content and suggestions about changing the size of the tools on different pages (e.g., TR-M2-Gal-FR007).
TR-	Should	5	Too much white	SF_2013_06_20_m6_p10 (Make pics as	Mentioned by many	33	

Gen-FR002	have		space on pages should be avoided in favour of larger or additional interface elements.	big as possible [Drawing tool, Faulkes Telescope Image]) CERN_2013_07_10_m1_g6_p2 (Too much empty space.)	participants on different occasions. Screen space should be used as efficient as possible, especially given the low resolution at some schools.		
TR-Gen-FR003	Should have	5	Go-Lab portal should offer elaborate help in addition to short help (TR-Gen-FR001).	SF_2013_06_20_m1_p1 (Insert "Help" button) CERN_2013_07_10_m3_g3_p1 ([include F1 as help button])	If TR-Gen-FR001 and instructions are clear enough, elaborated help might not be needed, but would still be beneficial.	14	
TR-Gen-FR010	Should have	5	An option to read it out loud should be added to every text in Go-Lab portal.	SF_2013_06_20_m1_p6 (Read it out loud option.)	Mentioned by several students. From our experience during the PD sessions many of the primary school students were struggling with reading long text. Having it read to them would help them. Issues might be that headphones are needed and content changes are much more complicated.	6	
TR-Gen-FR020	Should have	5	Current font should be changed and used consistently throughout the whole platform.	SF_2013_06_20_m1_test1 (Font change)	Some participants complained about the font currently used. Having the same font throughout the portal is very important for a consistent look.	13	

5.4.2 Requirements for the notes tool

Only one requirement about the notes tool has been rated as "must have". The "nice to have" requirements for this tool can be found in Table R (see Appendix C)

Table R3. Requirements for the notes Tool

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Notes-FR001	Must have	4	An option to show and hide the notes tool when needed must be given.	SF_2013_06_20_m2_p10 (good to minimise or make bigger when needed [Go-Lab Notes])	As it is a tool in the toolbar this functionality should already be included.	1

5.4.3 Requirements regarding a new tool proposed

Only one proposed tool requirement has been rated as "must have". The "should have" and "nice to have" requirements for this tool can be found in Table R16 in *Appendix B.*

Table R4. Requirements Proposed Tools

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-NewT-FR005	Must have	2	There must be a tool for the teacher to monitor progress.	RS_2013_06_21_m1_p3 (Tool to monitor progress for teacher.) RS_2013_06_21_m2_p4 (A tool should exist where teachers can see which tasks a student has completed and how long has been spent on the task. In some instances students may skip certain stages and in that scenario teachers should be able to prevent students from moving on to the next stage before it has been completed.)	This has been asked for by some participants. This might also be needed for grading and keeping track of the students' activities during class, but also depends on the pedagogical concept.	3

5.4.4 Requirements for instructions speech bubble tools

As there have been several requirements for the instructions speech bubble (Figure R1), which is used on several screens but does not serve as a tool, they have been collected in a separate table (Table R). Additional requirements can be found in Table R17 (see Appendix B).

Figure R1. Screenshot of Instructions speech bubble

Table R5. Requirements Instructions Speech Bubble

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Instr-FR003	Should have	4	"Previous and next button" in instruction speech bubble should be moved to the bottom of the screen.	SF_2013_06_20_m4_p3 (Maybe move these to the bottom of the page to allow you to move on after completing the activity instead of having to scroll back up to the top of the page.) CERN_2013_07_10_m5_test8 (Consider adding a copy of the "Previous" and "Next" buttons to the bottom of each page. It is the standard location on most web pages and the place that the students would look first.)	Especially on long pages this would be helpful. Additionally this would guide the students through the page and prevent moving on, while not done on the page (e.g., after reading the instructions without actually doing anything. On the other hand that might hinder fast navigation in sub-phases.	2
TR-Instr-FR004	Should have	4	An option to minimize (hide and show) it should be added to the instructions speech bubble. The book icon/button could be used to hide and show instructions.	SF_2013_06_20_m7_p5 (However maybe a minimize button [Info bubble]) SF_2013_06_20_m3_p3 (Can you click this [Info bubble book icon] again to hide the instructions once you've read them?)	Especially on screens where it covers other screen elements this is necessary. Given the small screen resolutions on some school computers, this would save screen space and thus help to have all elements currently needed visible.	3
TR-Instr-FR007	Should have	1	Next button in "Instruction speech bubble" should be more noticeable.	SCP_2013_07_01_m1_g3_p1 (the next [Next button] needs to be in a different colour to make it clearer)	The next button is important for the interaction with the portal. As part of the future design process, this could be taken into consideration.	2

5.4.5 Requirements for mockup screen 0 of interacting galaxies lab

The previous requirements have been clustered based on their general nature or tool they target. The following requirements are specifically for one single screen of the mockup. To ease the understanding of the requirements and user comments, a screenshot of the page on which the comment was made is given (in this case (Figure R2). Table R6 only shows the most important requirement, rated as "should have"; all other requirements have been put into Table R18 in Appendix B.
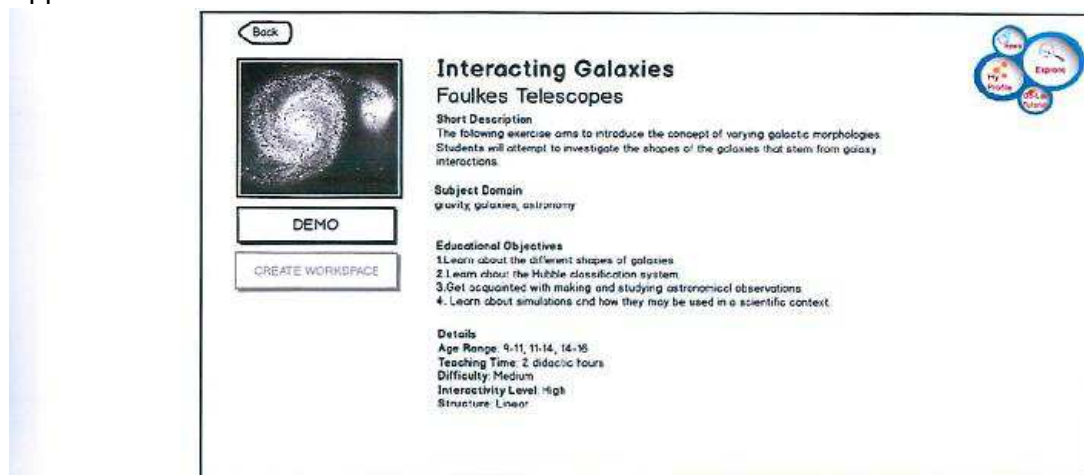

Figure R2. Screenshot of Interacting Galaxy mockup 0

Table R6. Requirements Galaxy Mockup 0

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-M0-Gal-FR003	Should have	1	"Subject Domain"s should link to UK National Curriculum.	RS_2013_06_21_m0_p3 (Links to UK National Curriculum [Subject domain])	This could help the teachers to choose the right labs.	1

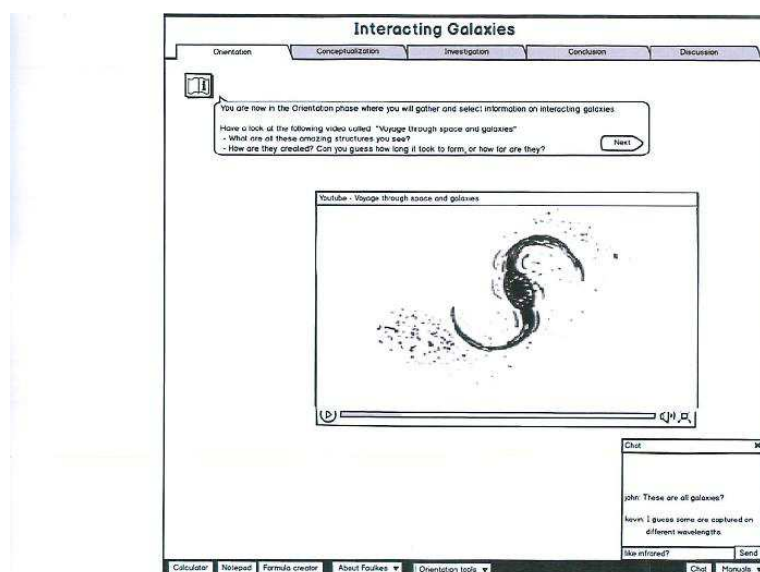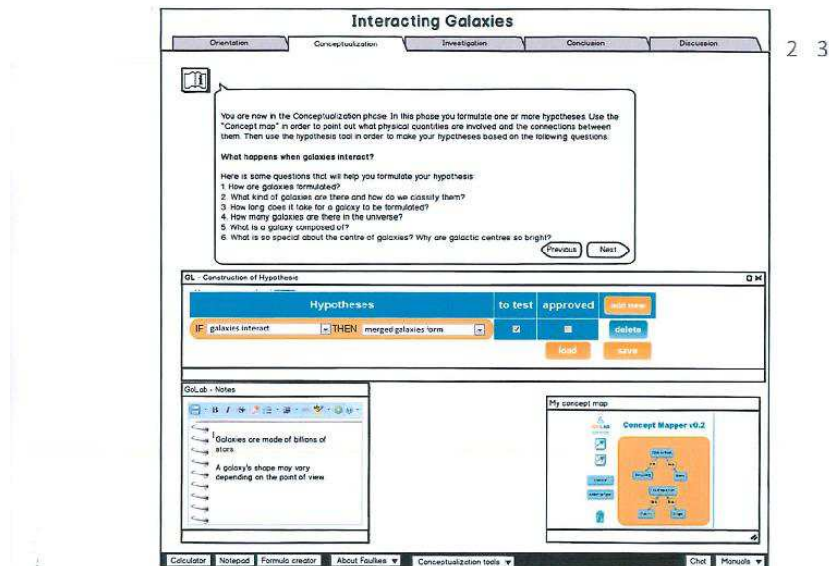### 5.4.6 Requirements for mockup screen 1 of Interacting Galaxies

Figure R3. Screenshot of Interacting Galaxy mockup 1

Table R7. Requirements Galaxy Mockup 1

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-M1-Gal-FR007	Should have	1	Video should be enhanced with additional information.	SF_2013_06_20_m1_test15 (Some information about the video clip - a brief overview, how long it is etc. Have you seen the BBC Learning Zone clips where they give some brief info about it.)	Several participants asked for additional information about the video.	5	TR-M1-Gal-FR004 and TR-M1-Gal-FR007are similar and also asking for more information about the video.

5.4.7 Requirements for mockup screen 2 of Interacting Galaxies

Figure R4.Screenshot of Interacting Galaxy mockup 2

Table R8. Requirements Galaxy Mockup 2

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-M2-Gal-FR002	Should have	3	Option to resize "My concept map" (up to full screen) should be added.	SF_2013_06_20_m2_p2 (Maybe an option that would let you make this [My concept map] full screen.)	More space might be needed to interact with the maps and to create larger maps. Schools have different screen resolutions and concept should be adaptable to that.	3

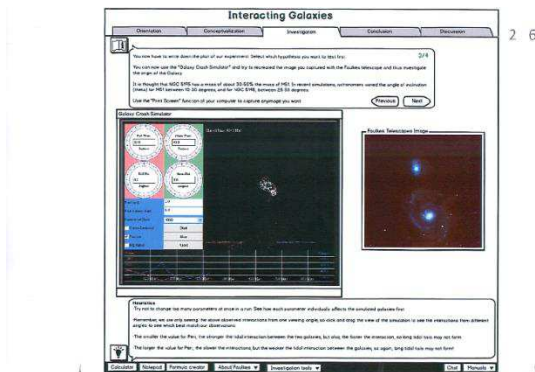### 5.4.8 Requirements for mockup screen 5 of Interacting Galaxies

Figure R5. Screenshot Of Galaxy Mockup 5

Table R9. Requirements Galaxy Mockup 5

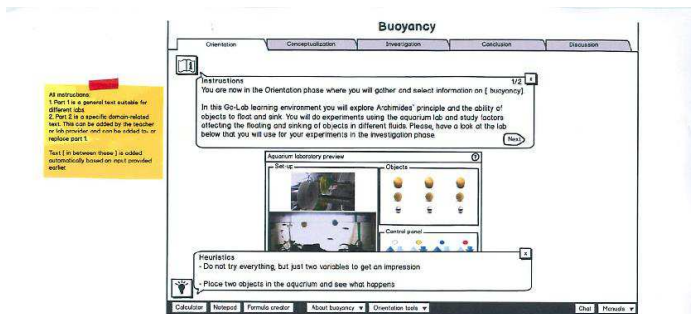| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-M5-Gal-FR005	Should have	2	Interface of "Galaxy Crash Simulator" should be made simpler.	SF_2013_06_20_m5_p5 (This [Galaxy Crash Simulator] looks way way way too complicated for simpletons like me.)	Mentioned by several participant. But if this is an external tool, which is included into the portal, it might be impossible to change it.	6

5.4.9 Requirements for mockup screen 1 of Buoyancy

Figure R6. Screenshot of Buoyancy mockup 1

Table R10. Requirements for Buoyancy Mockup 1

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-M1-Buo-FR001	Should have	1	The "Objects" in "Aquarium laboratory preview" should be described.	SCP_2013_07_01_m1_g1_p3 (What are these objects [Aquarium laboratory preview, Objects]? Something to tell me e.g key)	Several participants did not understand what those objects are, which is important to work with this lab.	4

6   Conclusion

Participatory activities in the Go-Lab project are indispensable for understanding different stakeholders' needs as well as goals and for evaluating how well the ongoing pedagogical and technical work of Go-Lab could actually or will potentially meet them. In the period of five months (March-August 2013), 25 Visionary Workshops (VWs) and 9 Participatory Design (PD) workshops have been conducted in nine and five countries, respectively. They involved altogether 685 teachers (490 in VWs and 195 in PD workshop) and 43 students, totalling to quite a high number of 728 participants. Clearly, the comprehensive datasets so gathered enable us to gain constructive insights into the future work of Go-Lab. Specifically, requirements have been extracted from the empirical data and prioritised in terms of necessity and impact. Amongst others, the main requirement is to render the Go-Lab Portal more child-friendly for young students, who can vary widely in terms of language and other cognitive abilities as well as social skills. This high-level requirement is supported by several other more specific ones (e.g., making the language more age-appropriate and consistent with those used in curricula). In addition, the quantitative and qualitative results also support us to address the research questions relevant to the pedagogical team and participatory design team.

Above all, based on the participants' feedback, it is very encouraging to observe that the general acceptance of Go-Lab is high. Specifically, the participants of VWs and PD workshops appreciated the key objectives of Go-Lab project, including the ideas of building online labs federation and developing a pedagogical framework based on the inquiry learning cycle to support the use of online labs. The participants were also optimistic about the direction the project has been taking, and were interested in finding out more information about the platform and to discover new laboratories matching their needs.

The participatory activities will be continued when the Go-Lab project progresses to the next phase when the executive prototypes will be ready for evaluation. Both VW, which are to be replaced by Practice Reflection Workshop in Year 2, and PD activities will be refined by modifying the current methods, techniques, and tools. Furthermore, online PD workshops will be launched, and a software tool for capturing feedback is under development and will be integrated into the Go-Lab Portal.

References

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2. Druin, A. (1999). Cooperative inquiry: Developing new technologies for children with children. In *Proceedings of CHI'99*. ACM Press.

3. Krippendorff, K. (2004). *Content analysis: An introduction to its methodology* (2nd ed.). London: SAGE.

4. Walsh, G., Druin, A., Guha, M., Foss, B., Golub, E., Hatley, L., Bonsignore, B., & Franckel, S. (2010). Layered Elaboration: A New Technique for Co-Design with Children. In *Proceedings of CHI 2010*.

5. Walsh, G., Foss, E., Yip, J.C., & Druin, A. (2013). FACIT PD: a framework for analysis and creation of intergenerational techniques for participatory design. In Proc.CHI 2013 (pp. 2893-2902).

6. Weber, R. P. (1990). *Basic Content Analysis*, (2nd Ed). Newbury Park, CA.

Appendix A: List of existing online labs

(NB: These online labs with embedded links have been used by the respondents to the Go-Lab Teacher Survey)

- 3D Vinci
- Bradford Robotic telescope
- Cisco Online Lab
- CoachLab II
- Education Scotland
- e-lab
- ESA kids
- Explorelearning
- Falstad
- Física con ordenador
- HHMI virtual labs
- Hipatia e Astrométrica
- iLabRs
- J-Track 3D Satellite Tracking
- Laboratório virtual universidade do minho
- micro-kosmos
- Modellus
- Molecular Expressions
- MONET,Faulkes,Phillips Cooperative
- mudelid
- National Schools Observatory
- NetLab
- Planet Impact
- Rrlab
- Schulphysik
- Seilias
- Tabela Periódica

Appendix B: Less Important Requirements

Table R11. Less Important Pedagogical Requirements

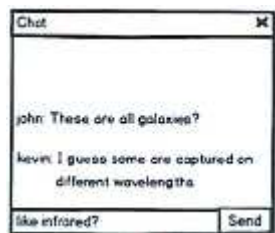| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
PR-Gen-FR008	Nice to have	1	Some conclusions could be suggested in the conclusion step.	SF_2013_06_20_m7_p1 (Suggest some conclusions [My conclusions])	As PR-Gen-FR006 asking for specific examples as a concrete way how to possibly improve conclusion step.	1
PR-Gen-FR010	Nice to have	1	"Educational Objectives" could be written using Blooms Taxonomy (understand, describe, explain, etc.).	SF_2013_06_20_m0_test14(2) (Could objectives be written using Blooms Taxonomy (understand, describe, explain, etc.)?)	Very specific requirement for a very small part of the portal.	1
TR-Gen-FR018	Nice to have	2	Additionally to the chat there could be a discussion forum in the platform.	SF_2013_06_20_m9_p3 (Maybe there could also be a discussion forum to discuss topics that can be viewed on the website with other students.)	This depends on the pedagogical concept and realization of discussion. This would be one option how to do it.	1
TR-Gen-FR019	Nice to have	2	Conclusions could be shared on the platform for further reference, comparison and discussion.	SF_2013_06_20_m9_p5 (might be nice to have a conclusion society - share data)	Depending on the usage scenario. If each lab is used only once during a lesson, this is not needed. Otherwise it could help to build a community and encourage communication.	5
TR-Gen-FR022	Nice to have	4	Students could be able to complete labs at home.	RS_2013_06_21_m5_p4 (Also students should be able to complete at home)	Depends on the pedagogical concept but might be complicated and time consuming to implement, if it includes not only continuing a started lab, but also asynchronous feedback to the teacher and other students.	1

Table R12. Less Important General Technical Requirements

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Gen-FR005	Should have	5	An option to switch between different languages would be nice.	SF_2013_06_20_m1_p5 (Options for more than one language anywhere?)	Although only mentioned by a few participants, this is a major requirement, if Go-Lab portal should be used in schools all over Europe. Of course this would be a lot of effort and thus might not be possible in Go-Lab project.	2
TR-Gen-FR007	Should have	5	User needs to be able to log out of the portal.	SF_2013_06_20_m1_p6 (log out option)	To be able to store and track the students' progress, accounts are desirable. On the other hand that means a lot of effort, thus this requirement depends on the overall user management concept.	1
TR-Gen-FR016	Should have	4	Page numbers could be added to each page of the labs.	SF_2013_06_20_m7_p1 (Insert page number)	Page numbers could help users to know where they are. But there are other ways to indicate the position in the current phase.	1
TR-Gen-FR009	Nice to have	4	Tabs for navigation could be at the bottom as well as on the top of the page.	SF_2013_06_20_m1_test7 (Maybe also the tabs need to be at the bottom as well as at the top?)	Interesting idea, which might be helpful especially on long pages, but which does not comply with the usual usage of the "tabs concept".	1
TR-Gen-FR013	Nice to have	5	An option to change the colour scheme could be included.	SF_2013_06_20_m4_p6 (On design, have changeable colour schemes to aid people with colour blind-ness or/and to make easier to read e.g., invert colours)	If the default colour scheme is good, there is no need for alternatives. Still some kind of "personalization" could encourage the users.	1
TR-Gen-FR015	Nice to have	5	There could be an option to display a sitemap to navigate through the pages.	SF_2013_06_20_m6_p6 (Could be very useful to have "site map" option to allow easier flipping through pages)	Navigation through the page should be based on inquiry learning approach and content of the pages. Thus a sitemap seems to not really be needed.	1
TR-Gen-FR023	Nice to have	4	Tabs could stand out more.	SCP_2013_07_01_m3_g5_p1 (Stand out more [tabs])	Only mentioned once. This is also not the final layout but only a prototype.	1
TR-Gen-FR024	Nice to have	5	Important phrases could stand out from the rest of the text.	SCP_2013_07_01_m4_g5_p1 (Important words or phrases have to stand out.)	Only mentioned once. This is also not the final layout but only a prototype.	1

Table R13. Less Important Requirements Toolbar

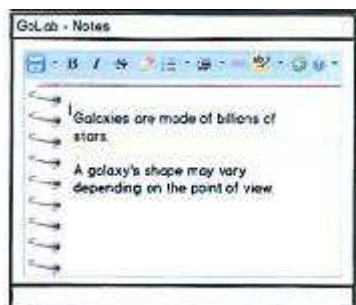| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-Tbar-FR001	Should have	4	Toolbar should be designed to be more recognizable.	SF_2013_06_20_m1_p2 (Could be bigger/more obvious)	Some participants mentioned this requirement. As the toolbar holds important tools to be used, it is important that it is easy to recognize.	6	
TR-Tbar-FR002	Nice to have	4	Toolbar could alternatively also be on the side.	SF_2013_06_20_m1_p3 (Could there be a menu bar down the side,)	The advantage would be that all the tools would be accessible at all the time even on long pages (if it moved to stay always in the visible area).	1	
TR-Tbar-FR003	Nice to have	3	Tools could be shown where there is currently whitespace on the pages.	SF_2013_06_20_m1_p5 (Maybe actually show these [Calculator, Notepad, Formula creator] in the surrounding white space?)	The issue with this requirement is that there is not always whitespace on the page.	2	More specific idea for: TR-Gen-FR002

Table R14. Less Important Requirements Chat Tool

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Chat-FR001	Should have	4	Abusing of chat should be prevented.	SF_2013_06_20_m1_p10 (Could be open to abuse [Chat]. Some would just have a chat and go off the task.)	Abusing of chat cannot really be prevented, but it should be limited.	2
TR-Chat-	Nice to have	2	It would be nice to have some smileys and other	SF_2013_06_20_m1_p1 (Insert Emoji =))	Emotions would make the chat more fun to use, but are not really	1

| FR002			icons to enrich the textual chat messages.		necessary for the communication.	
TR-Chat-FR003	Nice to have	4	It would be good if chat would not only be one-on-one but would also allow inviting a group of people.	SF_2013_06_20_m1_p6 (Can this invite multiple people e.g., a class discussion or group project) (cf. TR-Gen-FR018)	Functionality of chat needs to be tailored for its intended use for group work, asking the teacher for help, communicate with the whole class.	1
TR-Chat-FR004	Nice to have	1	Users could have an option to use a nickname of their choice in the chat tool.	SF_2013_06_20_m4_p1 (Chat name choices)	Nicknames might make it more complicated to identify the students, but could encourage them to use the chat.	1

Table R15. Less Important Requirements Notes Tool

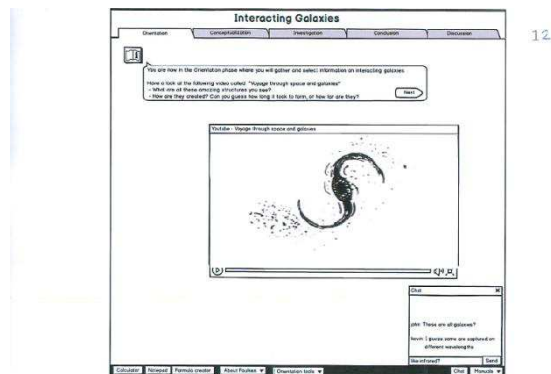| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Notes-FR002	Nice to have	3	A full screen mode for "Go-Lab - Notes" could be added.	SF_2013_06_20_m2_p3 (Option to have these [Go-Lab Notes] bigger as a full screen.)	Full screen mode would on one hand hide all other information but could help the students to concentrate on their notes.	1
TR-Notes-FR003	Nice to have	1	"Go-Lab – Notes" tool could allow free hand notes.	RS_2013_06_21_m1_p4 (An area for making notes might be useful either a text tool or free hand)	Not sure if the students would really benefit, might depend on the learning content.	1

Table R16. Less Important Requirements Proposed Tools

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-NewT-FR004	Should have	2	Additionally to the "Chat" tool there could be a tool to contact only the teacher (not to other students)	SF_2013_06_20_m4_test5 (Separate email for teachers/ a single person so people can ask anything they want without embarrassment [near chat button])	There should be a way to contact the teacher in case of questions or problems. But this could be realized in different ways (raising hand in classroom, included in chat, separate tool, …)	1
TR-NewT-FR001	Nice to have	2	There could be a "formula dictionary".	SF_2013_06_20_m2_p6 (Is there a formula dictionary? [Formula creator])	Really helpful for some topics, not needed for others.	1
TR-NewT-FR002	Nice to have	2	There could be a "Music Player" tool.	SF_2013_06_20_m4_p1 (Music player [image drawn])	Music player might distract students, but could also be used for refreshing short breaks.	1
TR-NewT-FR003	Nice to have	2	There could be a "Keyword" tool.	SF_2013_06_20_m1_test4 (There should be a keyword tab throughout that you can refer to if need be.)	As many participants raised problems with the wording, a tool explaining words would be helpful. On the other hand tool is only one option how to implement this, e.g., glossary would be another or TR-NewT-FR008.	1
TR-NewT-FR006	Nice to have	4	There could be a tool monitoring the progress and preventing the student from continuing if current page is not completed.	RS_2013_06_21_m2_p4 (A system of monitoring which tasks have been completed. If a student has skipped a certain stage then a tool should exist that prevents students from moving on to the next stage before completion)	Depends on the approach. If the students should freely explorer the labs, this is not needed; otherwise it would be helpful guidance.	2
TR-NewT-FR007	Nice to have	4	There could be a tool for time monitoring with an option to add more time to the time limit.	RS_2013_06_21_m5_p4 (Time monitoring with option to add more time to time limit.)	Depends on the approach. If the students should freely explorer the labs, this is not needed; otherwise it would be helpful guidance.	1
TR-NewT-FR008	Nice to have	4	There could be a tool which enables the user to click on words and get an explanation of them.	SCP_2013_07_01_m7_test6 (To have the ability to click on a word and it tells you what the word means.)	Like TR-NewT-FR003 one possible way to support students if they do not know the meaning of a word.	1

Table R17. Less Important Requirements Instructions Speech Bubble

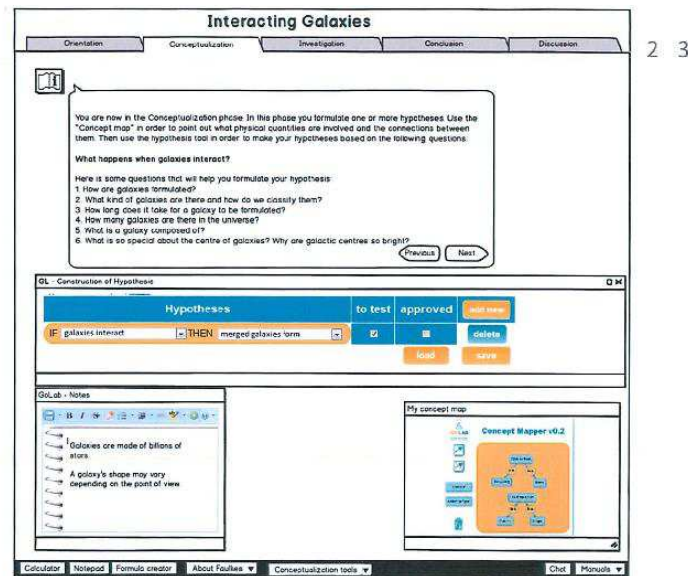| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-Instr-FR001	Should have	4	The book icon should be removed or replaced.	SF_2013_06_20_m1_p6 (Not really needed [book icon by Info bubble]/or you could put a logo or mascot.)	Some participants had an issue with this icon. As part of the future design process, this should be taken into consideration.	6
TR-Instr-FR005	Nice to have	4	Book icon/button could lead to additional information.	SF_2013_06_20_m2_test18(2) (The information sign [info bubble] should point to information useful them for the task.)	All necessary information need to be directly available for the students. Additional information could be made available; this would be one option of how to do it.	1
TR-Instr-FR006	Nice to have	4	"Instruction speech bubble" could be clearer.	SF_2013_06_20_m3_test15 (I would like to see the instruction bar clearer in some way but I'm not sure how. Text? Layout? Color?)	As part of the future design process, this could be taken into consideration.	1
TR-Instr-FR008	Nice to have	1	"Instruction speech bubble" could be moveable.	SCP_2013_07_01_m2_g4_p2 (Make it so you can move it about the page [Instructions].)	This could help on really large pages to reference back to the instructions.	1

Table R18. Less Important Requirements Galaxy Mockup 0
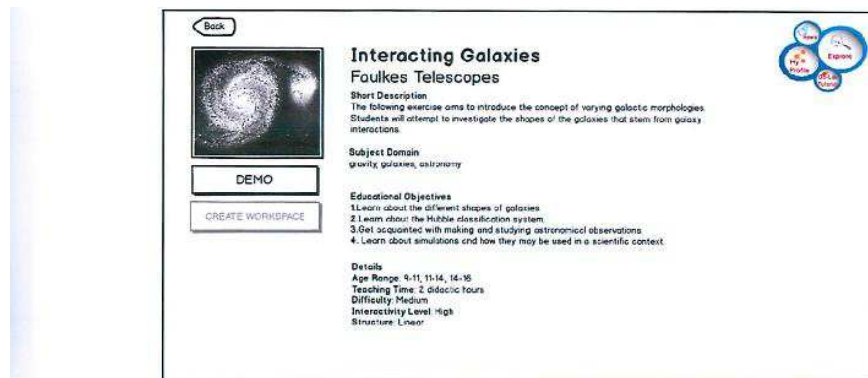
Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.
TR-M0-Gal-FR004	Nice to have	1	"Details" section could include additional information if the lab is intended for individual students or groupwork.	RS_2013_06_21_m0_p3 (Suggest whether groups, individual)	This could help the teachers to choose the right labs.	1

Table R19. Less Important Requirements Galaxy Mockup 1

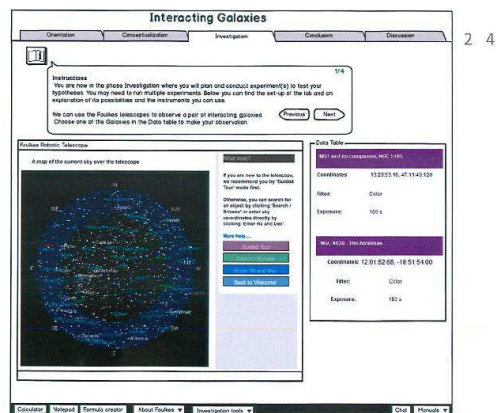| Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-M1-Gal-FR002	Should have	1	There should be a description of the video, in case it is not working.	SF_2013_06_20_m1_p4 (Add description about the video - in case the video doesn't work)	Especially given the fact that some schools are blocking video streaming sites and the equipment needed to listen to the video might not be available, this is a very good suggestion.	1	TR-M1-Gal-FR004 and TR-M1-Gal-FR007are similar and also asking for more information about the video.
TR-M1-Gal-FR001	Nice to have	1	Students could get the opportunity to answer the questions raised in the introduction by putting text input fields underneath.	SF_2013_06_20_m1_p1 (Need space to write the answers [in info bubble])	Students might not know the answers yet.	1	
TR-M1-Gal-FR003	Nice to have	2	The book icon could be changed to a face or something that could talk, to match the informal language in the speech bubble.	SF_2013_06_20_m1_p5 (If this symbol [book by the Info Bubble] was a face/something that could talk then the informal language is more acceptable)	As part of the future design process, this could be taken into consideration.	1	
TR-M1-Gal-FR004	Nice to have	1	It would be nice to have a transcript of the video.	SF_2013_06_20_m1_p5 (Transcript? [Video])	Especially given the fact that some schools are blocking video streaming sites and the equipment needed to listen to	5	TR-M1-Gal-FR001 and TR-M1-Gal-FR007are similar and also asking for

					the video might not be available, this is a very good suggestion. But as transcript might be very time consuming or not available, a detailed description of the content might be enough.		more information about the video.
TR-M1-Gal-FR005	Nice to have	1	If the direct link to the video would be accessible, it would be possible to send the video or watch it again later.	SF_2013_06_20_m1_p5 (Or direct link to video should they want to send the video on or view it again in their own time.)	Not sure if the students would actually do this, but might be worth consideration.	1	
TR-M1-Gal-FR006	Nice to have	1	It would be nice, if a transcript of the video could be printed for later reference.	SF_2013_06_20_m1_p6 (Able to print off [transcript of video] to refer back to.)	Not sure if the students would actually do this, but might be worth consideration.	1	Transcript is needed to be able to print it (TR-M1-Gal-FR004).
TR-M1-Gal-FR008	Nice to have	1	This page could contain more information e.g., more videos.	RS_2013_06_21_m1_p2 (more information) RS_2013_06_21_m1_p2 (more videos)	As there is a lot of white space, something should be changed on this page.	1	
TR-M1-Gal-FR011	Nice to have	1	Video player could include an option to specify which part(s) to watch.	RS_2013_06_21_m1_p4 (Being able to select segments [video] so students can select specific parts of the clip to watch)	This would be especially helpful for long or complicated video clips.	1	

Table R20. Less Important Requirements Galaxy Mockup 2

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-M2-Gal-FR007	Should have	3	All tools on this page should be larger or maybe even on a whole, new page.	SF_2013_06_20_m2_p6 (Great tools here, yet need to be larger or even on a separate page/subpage)	Currently the tools are hard to read and could be difficult to work with.	3	Included in the more general requirement to have adequate size of all tools on pages (TR-Gen-FR025). This might even eliminate the need for the user to resize the tool himself (TR-M2-Gal-

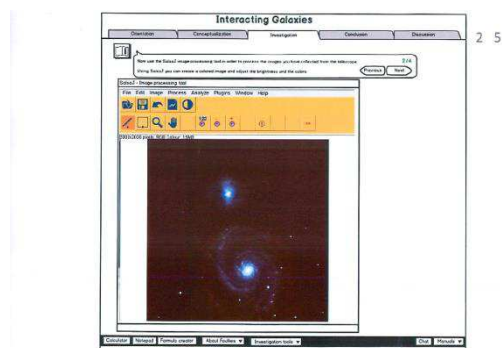|						
						FR002).
TR-M2-Gal-FR001	Nice to have	1	Instead of numbering bullet points might be used in information speech bubble.	SF_2013_06_20_m2_p1 (Bullet points)		1	
TR-M2-Gal-FR003	Nice to have	2	A button to open and close "My concept map" would be nice.	SF_2013_06_20_m2_p3 (Button to open up each window [My concept map] individually.)		1	
TR-M2-Gal-FR004	Nice to have	1	User could be enabled to answer the questions asked in the "Instructions speech bubble".	SF_2013_06_20_m2_test4 (It would be nice to have somewhere to write a response to the questions asked at the top of the screen. Possibly by having the questions in the note box at the bottom of the screen.)		1	
TR-M2-Gal-FR005	Nice to have	2	Information speech bubble could be smaller.	SF_2013_06_20_m2_p5 (Is there any way that this [Info bubble] can take up less space?)		1	
TR-M2-Gal-FR008	Nice to have	2	Information speech bubble could be stretched out.	SF_2013_06_20_m2_p6 (Stretch box [Info bubble] out.)		1	
TR-M2-Gal-FR009	Nice to have	3	Interface elements could be set out better on this screen.	RS_2013_06_21_m2_p2 (set out better [Mockup])		1	Similar to TR-M2-Gal-FR007 but not necessarily about size.
TR-M2-Gal-FR010	Nice to have	2	Teachers could be enabled to edit the "GL – Constructions of Hypothesis" tool.	RS_2013_06_21_m2_p3 (Great idea - can teachers edit this? [Hypothesis tool])		1	

Table R21. Less Important Requirements Galaxy Mockup 3

Code	Obligation	Impact Index	Description	Example	Reasoning for obligation	Freq.	Additional Information
TR-M3-Gal-FR003	Should have	1	"Map of the current sky over the telescope" should be bigger.	SF_2013_06_20_m3_p1 (bigger picture [Faulkes tool])	There is a lot of text on this picture, which is hard to read if the map is too small.	3	Related to TR-M2-Gal-FR007
TR-M3-Gal-FR001	Nice to have	3	"Faulkes Robotic Telescope" could fill the whole page.	SF_2013_06_20_m3_p10 (This [Faulkes Robotic Telescope] could fill the page)		1	
TR-M3-Gal-FR002	Nice to have	3	"Data Table" could be moved into "Faulkes Robotic Telescope".	SF_2013_06_20_m3_p10 ([Data Table - moved into - Faulkes Robotic Telescope window])		1	
TR-M3-Gal-FR004	Nice to have	1	"Map of the current sky over the telescope" could allow zooming.	SF_2013_06_20_m3_p1 (zoom in and out [Faulkes tool])		4	
TR-M3-Gal-FR005	Nice to have	1	"Map of the current sky over the telescope" could allow reading about the stars, constellations and galaxies.	SF_2013_06_20_m3_p1 (Read about the galaxies [Faulkes tool])		2	
TR-M3-Gal-FR007	Nice to have	2	There could be a box with keys or keywords besides the instructions speech bubble.	SF_2013_06_20_m3_p4 (Keys/keyword [box besides instructions])		1	Related to requirements suggesting keyword tools (TR-NewT-

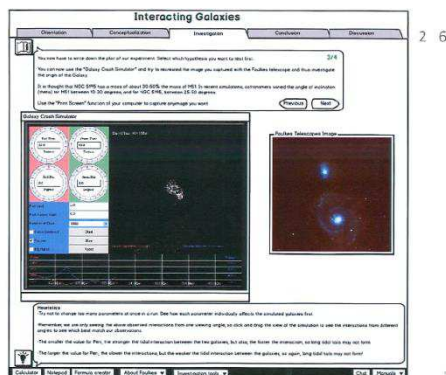|							
					FR003 and TR-NewT-FR008).		
TR-M3-Gal-FR008	Nice to have	2	"Data Table" could be larger than "Faulkes Robotic Telescope" because the student has to choose one of the galaxies there to continue.	SF_2013_06_20_m3_p4 (If this [Data table] is the task then it should be bigger than the Faulkes Robotic Telescope screen?)		1	
TR-M3-Gal-FR009	Nice to have	1	Page numbers in information speech bubble might need to be designed more recognizable.	SF_2013_06_20_m3_p6 ([Info bubble, 1/4 label] Good for separating information But may be missed if not seen)		1	
TR-M3-Gal-FR010	Nice to have	1	"Map of the current sky over the telescope" could allow filtering the content.	SF_2013_06_20_m3_p6 (Also able to filter for just constellations / planets / galaxies [Faulkes Robotic Telescope])		2	
TR-M3-Gal-FR011	Nice to have	1	Buttons or font on buttons in "Faulkes Robotic Telescope" tool could be larger.	SF_2013_06_20_m3_p6 (Larger buttons/font [Faulkes Robotic Telescope, more help buttons])		1	
TR-M3-Gal-FR012	Nice to have	1	Some explanation or a dictionary of keywords could be added to the terms used in "Data Table"	SF_2013_06_20_m3_p6 (Some explanation/dictionary of key words [Data Table])		3	Related to requirements suggesting keyword tools (TR-NewT-FR003 and TR-NewT-FR008).
TR-M3-Gal-FR013	Nice to have	2	Layout of information speech bubble could be better.	RS_2013_06_21_m3_p1 (Better layout [Info bubble])		1	
TR-M3-Gal-FR014	Nice to have	1	Font on buttons in "Faulkes Robotic Telescope" tool could have a different colour.	RS_2013_06_21_m3_p1 (The text, a different colour [Faulkes Robotic Telescope, buttons])		1	
TR-M3-Gal-FR015	Nice to have	1	Font of text in "Faulkes Robotic Telescope" tool could be changed.	RS_2013_06_21_m3_p2 (change font [Faulkes Robotic Telescope, description])		1	
TR-M3-Gal-FR016	Nice to have	1	Buttons in "Faulkes Robotic Telescope" tool could be less colourful.	RS_2013_06_21_m3_p2 (Less colour [Faulkes Robotic Telescope, buttons])		1	
TR-M3-Gal-	Nice to have	2	Hypothesis could be shown beneath "Faulkes	RS_2013_06_21_m3_p3 (Show hypothesis)		2	

Code	Obligation	Impact Index	Description	Example	Freq.
FR017			Robotic Telescope" tool.		
TR-M3-Gal-FR018	Nice to have	1	"Filter" in "Data Table" could provide a drop down list to choose filter from.	RS_2013_06_21_m3_p3 (Allow drop down list [Data table, filter])	1
TR-M3-Gal-FR019	Nice to have	1	"Exposure" in "Data Table" could give a range instead of a single value.	RS_2013_06_21_m3_p3 (Give a range [Data table, exposure])	1
TR-M3-Gal-FR020	Nice to have	3	There could be an option to minimize "Data Table" and thus enlarge "Faulkes Robotic Telescope" tool.	RS_2013_06_21_m3_p4 (Need to be able to minimize these [Data table] so that the image can be expanded)	1	Related to TR-M2-Gal-FR007.

Table R22. Less Important Requirements Galaxy Mockup 4

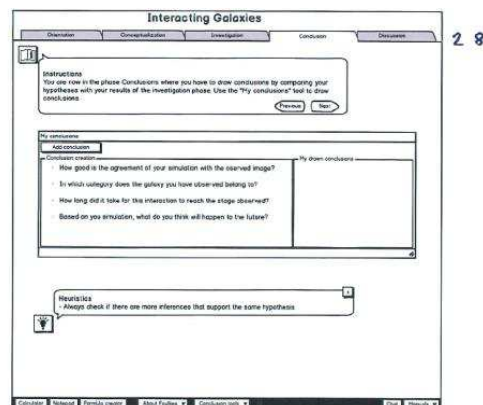| Code	Obligation	Impact Index	Description	Example	Freq.
TR-M4-Gal-FR002	Nice to have	1	Preview images of the galaxy image before and after processing it in SalsaJ might be added besides the "SlasaJ – Image processing tool" tool.	SF_2013_06_20_m4_p5 (Maybe small scale images [drew "old" and "new" icons] to directly compare originals/edited versions to see if it's worth changing!)	1
TR-M4-Gal-FR003	Nice to have	1	Blank buttons in SalsaJ tool could be removed (or their functionality displayed).	SF_2013_06_20_m4_p6 (Blanks? [SalsaJ toolbar])	1
TR-M4-Gal-FR004	Nice to have	1	Users could be given the option to save the image of the galaxy.	SF_2013_06_20_m4_p6 (Able to save image, because everyone loves pretty galaxies)	1

| TR-M4-Gal-FR005 | Nice to have | 3 | "SalsaJ – Image processing tool" tool could be centred. | SF_2013_06_20_m4_test4 (This [SalsaJ tool] needs to be centered!!!!) | 3 |
| TR-M4-Gal-FR007 | Nice to have | 3 | This page could be enhanced with more information. | RS_2013_06_21_m4_p1 (put some info about the page [right white space]) | 1 |

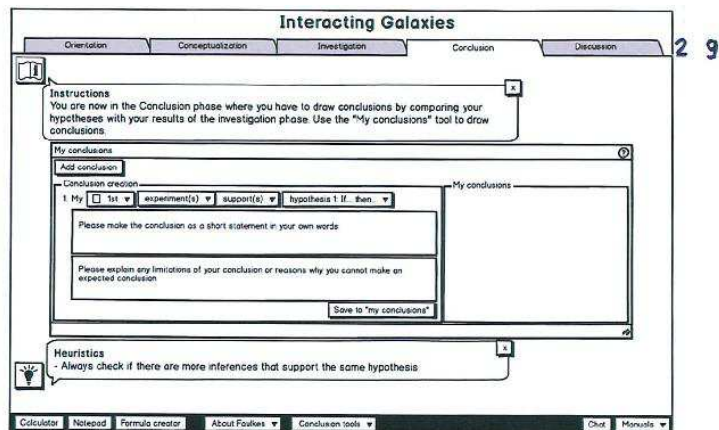**Table R23. Less Important Requirements Galaxy Mockup 5**

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M5-Gal-FR002	Nice to have	2	A gallery could be created from all the captured images.	SF_2013_06_20_m5_p1 (gallery from captured images)	1	
TR-M5-Gal-FR004	Nice to have	1	Instead of using "Print Screen" this functionality could be added to the tool.	SF_2013_06_20_m5_p3 (Could there [Info bubble] be the option to save images to your computer/memory stick instead of having to print screen)	2	
TR-M5-Gal-FR006	Nice to have	2	Interface elements on this page could be more separated and defined with more symmetry.	SF_2013_06_20_m5_test3 (Boxes should be more separated and defined, possibly more symmetry.)	1	
TR-M5-Gal-FR007	Nice to have	2	Interface of "Galaxy Crash Simulator" could be set out better.	RS_2013_06_21_m5_p2 (set out better [Galaxy Crash Simulator])	1	
TR-M5-Gal-FR008	Nice to have	2	Approach described in "Heuristics" might not be ideal.	SF_2013_06_20_m5_p6 (Will this [Heuristics, "try not to change too many parameters"] encourage people to try it?!) RS_2013_06_21_m5_p3 ([Heuristics, "each parameter individualy"] instead limit choices eg change one thing.)	2	Related to TR-M5-Gal-FR005

Table R24. Less Important Requirements Galaxy Mockup 6

Code	Obligation	Impact Index	Description	Example	Freq.
TR-M6-Gal-FR003	Nice to have	1	Image in "Drawing tool" could have a lighter colour.	RS_2013_06_21_m6_p2 (lighter colours [Galaxy Crash Simulator])	1
TR-M6-Gal-FR004	Nice to have	3	User could be able to drag semi-transparent version of image in "Drawing tool" over "Faulkes Telescope Image" to compare both.	RS_2013_06_21_m6_p4 (Image [Gaulkes Telescopes Image] could be made partially transparent to drag on the generated image for comparison. [arrow to drawing tool])	1

Table R25. Less Important Requirements Galaxy Mockup 7

Code	Obligation	Impact Index	Description	Example	Freq.
TR-M7-Gal-FR002	Nice to have	1	"My drawn conclusions" box in "My conclusions" tool could be bigger.	SF_2013_06_20_m7_p1 (Bigger conclusion box)	5
TR-M7-Gal-FR004	Nice to have	1	"My drawn conclusions" box in "My conclusions" tool could be a WYSIWYG editor.	SF_2013_06_20_m7_p4 (Choose fonts [My drawn conclusions])	3
TR-M7-Gal-FR007	Nice to have	3	"Conclusion" page could be more structured.	SF_2013_06_20_m7_test17 (Not as much thought seems to have gone into the designing of this page. Weaker students will not understand these questions [My conclusion tool] and how to answer them. I think it needs to be a more structured conclusion.)	1
TR-M7-Gal-FR008	Nice to have	2	The "Instructions speech bubble" on this page could be smaller.	SF_2013_06_20_m7_test1 (I do not like the instruction box, too big.)	1
TR-M7-Gal-FR009	Nice to have	2	There could be a box added explaining what "Conclusion phase" means.	RS_2013_06_21_m7_p3 ([Info bubble, "Conclusion"] box explaining what is meant.)	1
TR-M7-Gal-FR010	Nice to have	2	Hypothesis created during concept phase could be displayed between "Instructions speech bubble" and "My conclusions".	RS_2013_06_21_m7_p3 (Show hypothesis from concept phase.)	1

Table R26. Less Important Requirements Galaxy Mockup 8

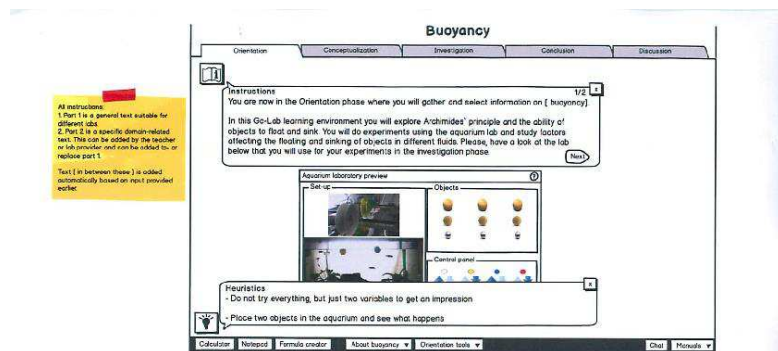| Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M8-Gal-FR001	Nice to have	1	Lab could give examples of conclusions	SF_2013_06_20_m8_p4 (Give examples of conclusion [My drawn conclusions])	2	Related to TR-M7-Gal-FR001
TR-M8-Gal-FR002	Nice to have	1	Instead of drop-down boxes to choose predefined options from the students could be allowed to create their own conclusions in the "My conclusions" tool.	SF_2013_06_20_m8_p5 (Not a fan of being pushed towards conclusions. If you have made the effort to do the experiment you don't need drop down boxes.)	1	Related to TR-M7-Gal-FR001
TR-M8-Gal-FR004	Nice to have	1	Questions from the last page could be included at the bottom of this page.	SF_2013_06_20_m8_test5 (Include the questions from the last page at the bottom of this page to help with this [My conclusions].)	1	
TR-M8-Gal-FR005	Nice to have	1	There could be the option to send the conclusion only to the teacher.	SF_2013_06_20_m8_test5 (Include an option to send the conclusion just to the teacher.)	1	
TR-M8-Gal-FR007	Nice to have	3	Interface elements could be set out better on this screen.	RS_2013_06_21_m8_p1 (to[o] cramped [?] (could be spread out))	1	Related to TR-Gen-FR025, TR-Gen-FR006 and TR-Gen-FR004
TR-M8-Gal-FR008	Nice to have	1	"Please make the conclusion as a short statement in your own words" could allow for a guided choice.	RS_2013_06_21_m8_p3 (Allow guided choice [My conclusions, Conclusion creation])	1	

Table R27. Less Important Requirements Galaxy Mockup 9

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M9-Gal-FR001	Nice to have	2	At the end of the lab, there could be a celebration page.	SF_2013_06_20_m9_p1 (Celebration page)	1	
TR-M9-Gal-FR002	Nice to have	2	At the end of the lab, there could be a finish button.	SF_2013_06_20_m9_p1 (Finish button)	2	
TR-M9-Gal-FR004	Nice to have	1	There could be an option to save the poster created to the hard drive or website.	SF_2013_06_20_m9_p3 (Could there be an option to save your poster to your computer or even to the website for other students to view and use to help them/for revision? [Info bubble])	1	Related to TR-Gen-FR018 and TR-Gen-FR019
TR-M9-Gal-FR005	Nice to have	1	Each section of the "My report" tool could go full screen when you click on it.	SF_2013_06_20_m9_p3 (or fill the screen when you click each section [My report])	1	
TR-M9-Gal-FR006	Nice to have	1	There could be a save button.	SF_2013_06_20_m9_p3 (Could there be a save button in case you need to come back to it later?)	1	Not necessary if TR-Gen-FR014 is fulfilled.
TR-M9-Gal-FR007	Nice to have	1	There could be a button to submit conclusion.	SF_2013_06_20_m9_p5 (Submit conclusion [button proposed],)	1	This is an alternative to auto-save (TR-Gen-FR014) combined with finish button (TR-M9-Gal-FR002).
TR-M9-	Nice to	1	Part of the "My report" tool	SF_2013_06_20_m9_p6 (automatically put in	1	

Code	Obligation	Impact	Description	Example	Freq.	Additional
Gal-FR008	have		could be filled out automatically from earlier pages.	from other stages)		
TR-M9-Gal-FR009	Nice to have	1	"Data to support or reject hypothesis 1" in the "My report" tool could include an option to specify "reject" or "support".	SF_2013_06_20_m9_p6 (Option "reject" or "support" [My report, Data to support or reject hypothesis])	1	
TR-M9-Gal-FR010	Nice to have	1	There could be a button to publish conclusion, with an option to send it to the teacher first.	SF_2013_06_20_m9_p6 (Option to be published [button proposed] -> email/send to teacher first)	1	This is an alternative option to TR-M9-Gal-FR007.
TR-M9-Gal-FR011	Nice to have	1	"My report" tool could offer text tools.	SF_2013_06_20_m9_p6 (Text tools [My report])	1	TR-M7-Gal-FR004 is another specific example of this requirement for a different text field.
TR-M9-Gal-FR016	Nice to have	1	"My report" tool could show suggestions by other students.	RS_2013_06_21_m9_p3 (Should see other students suggestions)	1	Related to TR-Gen-FR018 and TR-Gen-FR019

Table 28. Less Important Requirements Buoyancy Mockup 1

Code	Obligation	Impact	Description	Example	Freq.	Additional

		Index				Information
TR-M1-Buo-FR002	Nice to have	1	This page could be set out more neatly.	SCP_2013_07_01_m1_g3_p2 (It should be set out more neatly)	2	Related to TR-Gen-FR004 and TR-Gen-FR025
TR-M1-Buo-FR003	Nice to have	1	There could be a scroll bar besides "Aquarium laboratory preview".	SCP_2013_07_01_m1_g3_p3 (There should be a scroll on here [Aquarium laboratory preview])	1	Might not be necessary, if TR-M1-Buo-FR002 is fulfilled.
TR-M1-Buo-FR005	Nice to have	1	Images in "Aquarium laboratory preview" could be clearer.	SCP_2013_07_01_m1_g5_p1 (Clearer photos [Aquarium laboratory preview])	5	
TR-M1-Buo-FR006	Nice to have	1	"Light bulb icon" in front of "Heuristics" could be replaced.	SCP_2013_07_01_m2_g2_p2 (I do not understand why you put lightbulb here)	6	

Table R29. Less Important Requirements Buoyancy Mockup 3
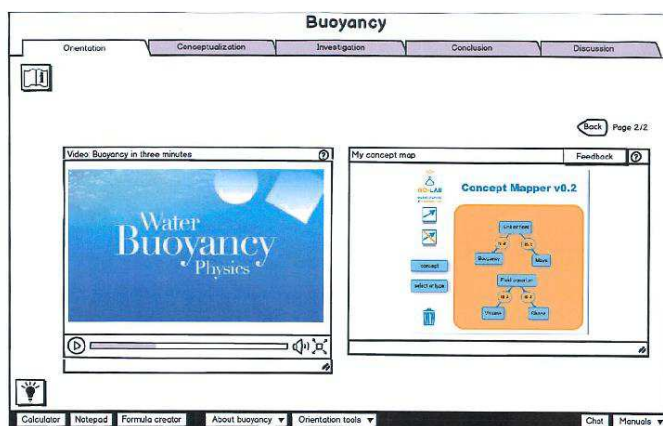
Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M3-Buo-FR002	Nice to have	4	"// icon" could be changed or explained.	SCP_2013_07_01_m3_g3_p1 (What is this for? [// icon to resize video])	3	Related to TR-Gen-FR001
TR-M3-Buo-FR004	Nice to have	1	"Video: Buoyancy in three minutes" could have subtitles.	SCP_2013_07_01_m3_g4_p1 (Should have subtitles [video])	1	Related to TR-M1-Gal-FR004
TR-M3-Buo-FR006	Nice to have	1	"Video: Buoyancy in three minutes" could show, how long the video duration is.	SCP_2013_07_01_m3_g5_p2 (Tell how long the video is.)	1	

Table R30. Less Important Requirements Buoyancy Mockup 4
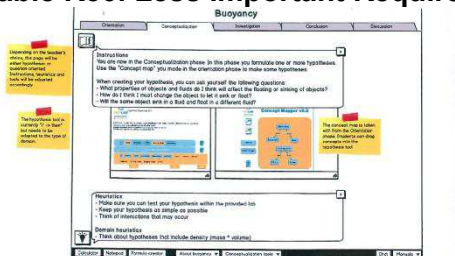
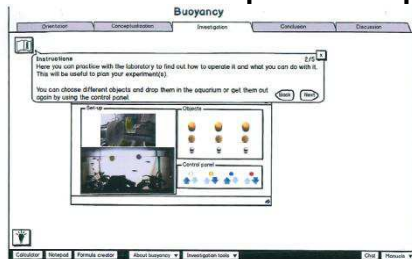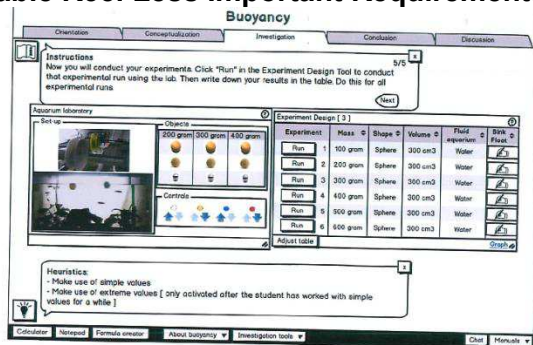| Code	Obligation	Impact Index	Description	Example	Freq.
TR-M4-Buo-FR001	Nice to have	1	"Next button" could be added to the "Instructions speech bubble".	SCP_2013_07_01_m4_g1_p3 (Why is there no next button?)	1

Table R31. Less Important Requirements Buoyancy Mockup 5
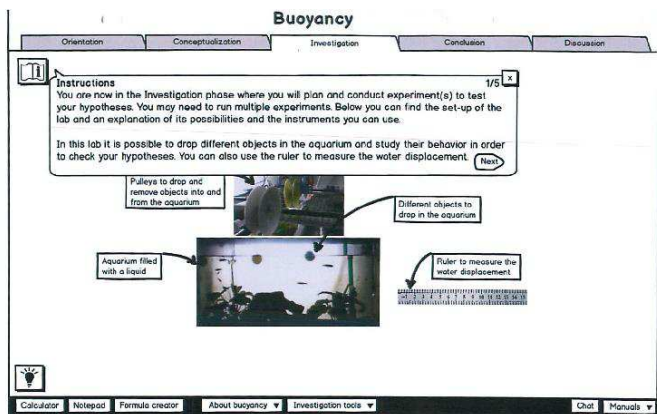
Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M5-Buo-FR001	Nice to have	1	Images on this page could be larger.	SCP_2013_07_01_m5_g1_p1 (Bigger photos)	1	
TR-M5-Buo-FR003	Nice to have	1	Images on this page could be brighter and more colourful.	SCP_2013_07_01_m5_g4_p2 (Make bright picture [image descriptions])	2	Related to TR-M1-Buo-FR005

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M5-Buo-FR005	Nice to have	1	The numbers on the ruler could stand out more.	SCP_2013_07_01_m5_g5_p1 (Make the numbers stand out [ruler])	1	

Table R32. Less Important Requirements Buoyancy Mockup 6

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M6-Buo-FR004	Nice to have	1	There could be a button which displays labels on the pictures.	SCP_2013_07_01_m6_test6 (Have a button to press if you want the pictures labeled . And make it so that you can see the button clearly.)	1	

Table R33. Less Important Requirements Buoyancy Mockup 7
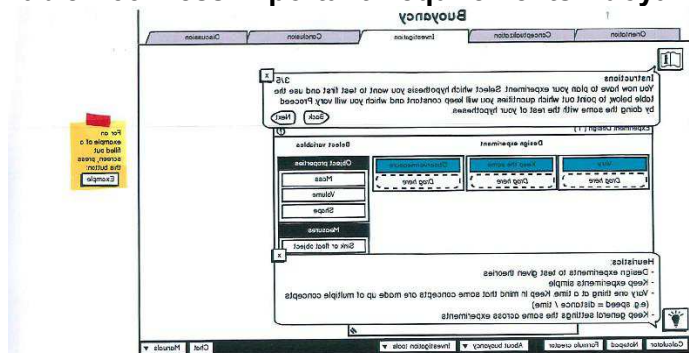
Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M7-Buo-FR001	N	3	This page could be more child-friendly.	SCP_2013_07_01_m7_g3_p2 (More child friendly [Exp. design])	4	Specific example for general requirement "Go-Lab portal must be child-friendly."

Table R34. Less Important Requirements Buoyancy Mockup 8
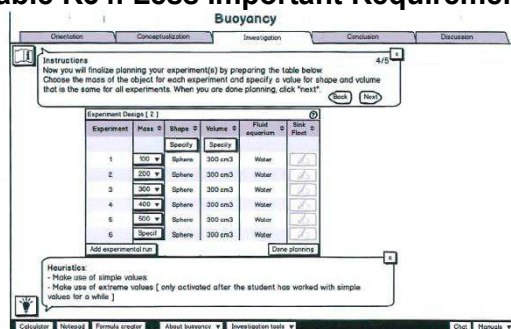
Code	Obligation	Impact Index	Description	Example	Freq.
TR-M8-Buo-FR001	Nice to have	2	"Experiment Design [2]" could be easier to understand.	SCP_2013_07_01_m8_g2_p1 (You could make this a bit more understanding [Exp. design])	2

Table R35. Less Important Requirements Buoyancy Mockup 9

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M9-Buo-FR001	Nice to have	2	"Experiment Design [3]" could be easier to understand.	SCP_2013_07_01_m9_g2_p1 (Don't understand this [Experiment Design [3]])	1	Specific example for general requirement "Go-Lab portal must be child-friendly."

Table R36. Less Important Requirements Buoyancy Mockup 12

Code	Obligation	Impact Index	Description	Example	Freq.	Additional Information
TR-M12-Buo-FR001	Nice to have	1	"My report" tool could be simpler.	SCP_2013_07_01_m11_g2_p2 (A bit advanced for kids [My report])	2	Specific example for general requirement "Go-Lab portal must be child-friendly."

Appendix C: How to retrieve more detailed information

The data unit identifier specified in the example column holds the information needed to retrieve the original comment which caused the creation of each requirement. It starts with the abbreviation of the school (**SCP**_2013_07_01_m2_g3_p1) at which the data was collected (either SF = Southfield, RS = Robert Sutton or SCP = St. Cuthberts' Primary), followed by the date of the participatory design workshop (SCP_**2013_07_01**_m2_g3_p1). The next part identifies the number of the mockup (SCP_2013_07_01_**m2**_g3_p1) and the end holds information about the participant who gave the comment (SCP_2013_07_01_m2_g3_**p1**, either p*X* for paper-based or test*X* for computer-based evaluation. The students at St Cuthberts' Primary School worked in groups, thus there is an additional group identifier before the participant ID: SCP_2013_07_01_m2_**g3**_p1).

To retrieve the original comment either Adobe Photoshop or the freeware Gimp (http://www.gimp.org/) is needed. On Graasp the digitized data from all three schools can be found (https://graasp.epfl.ch/#url=golabdata [SF: https://graasp.epfl.ch/#item=space_4480; RS: https://graasp.epfl.ch/#item=space_4484; SCP: https://graasp.epfl.ch/#item=space_4489]). If the data unit identifier ends with p*X* the file containing it can be found under "Scanned results – (either Photoshop or Gimp, depending on the software you are using to view it)", if it ends with test*X* it will be under "Computer-based evaluation". Next the mockup needs to be identified and downloaded. After opening the file, the comments will be accessible by unhiding the layer labelled with the data unit identifier.

To see the for example the comment SCP_2013_07_01_m1_g2_p2 using Gimp, the following steps are carried out:

- Go to section "GoLab data" in Graasp: https://graasp.epfl.ch/#url=golabdata
- **SCP**_2013_07_01_m1_g2_p2 -> Open space "PD Results (ULEIC) - St. Cuthberts"
- SCP_2013_07_01_m1_g2_**p2** -> Open space "Scanned Results - Gimp"
- SCP_2013_07_01_**m1**_g2_p2 -> Open and download resource "Mockup 1"
- **SCP_2013_07_01_m1**_g2_p2 -> Open downloaded file (SCP_2013_07_01_m1.xcf) in Gimp
- **SCP_2013_07_01_m1_g2_p2** -> Click in front of the layer "SCP_2013_07_01_m1_g2_p2.png" in "Layers" window, to make those comments visible.

To retrieve even more information (data unit identifiers of all comments associated with each requirement) the document "ListOfRequirements_final.xls" on Graasp (https://graasp.epfl.ch/#item=asset_12498) can be used. It includes one worksheet for each table in this document, where each requirement can be found, together with a list of all comments corresponding to it.

Figure 9. Requirement Pr-Gen-Fr004 And Data Unit Identifiers Of Associated Comments

To retrieve all the comments the process described above can be used. A transcription of all comments and the associated requirement codes can also be found in Graasp (https://graasp.epfl.ch/#item=space_4792; paper-based: https://graasp.epfl.ch/#item=asset_12500; computer based: https://graasp.epfl.ch/#item=asset_12499).