A Survey on the Usage of Online Labs in Science Education: Challenges and Implications

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***Abstract*—To provide teachers and students with more usable, desirable and useful online labs, the foremost step is to understand their existing usage patterns and experiences with such labs. This step was implemented with two online surveys, one targeting teachers and the other students. Altogether 915 respondents from 23 European countries were involved. Results indicate that the prevalence of online labs adoption was generally low and that the users had positive experiences despite some challenges such as difficult access (domain-specific labs) and language barrier (English user interface). Among others, a significant implication is to create a repository (portal) where resources can be used and shared with ease and enjoyability.**

Keywords—survey; online labs; science education; usability; user experience

I. Introduction

The aim of the Go-Lab project is to support science learning by adding online labs to science lessons [1]. Online labs, which can be divided into virtual and remote laboratories, provide interactive experiments over the Internet. Virtual labs are digital simulations of equipment and processes, whereas remote labs have real equipment that can be operated from a distance to observe the real results [2]. To achieve this goal the online Go-Lab Portal is developed to support teachers in identifying and utilizing appropriate online labs and to support students in accessing and working with the learning content and tools provided by their teachers.

From the usability [3] and user experience (UX) [4] perspective, the information on the usage of computing technologies in general and of online labs in particular by target end-user groups is very important for a development team to design the right user interface to deliver positive experience. Based on such information, designers can reason on possible future usage of the Portal and identify requirements regarding its desired look-and-feel. Being aware of existing issues can not only prevent their recurrence in designing and creating the new Portal but also improve the overall design by addressing those issues with alternative approaches.

To get an overview of the current usage of online tools and labs in European STEM (Science, Technology, Engineering and Mathematics) education, a survey has been created and conducted. The results and findings of this survey are reported in this paper, together with the implications for usability and user experience design for the Go-Lab Portal and its components to be used in STEM education.

The main focus of this study is on the usability and user experience of deploying existing online tools and labs in a classroom setting. This focus leads to two research questions (RQs):

RQ1: What can be learned from the current state of software tool and online lab usage in schools to improve European STEM education?

RQ2: Which implications can be drawn from the current user experience when interacting with software tools and online labs for the development of online components for teachers and students?

II. State Of The Art

The European Commission published a report on "ICT in Education" (ICT is an acronym for Information and Communications Technology) in 2013, based on data collected and analyzed in the school years 2011-12[1]. Three of their main findings interesting for online lab usage at schools are (ibid. p. 33):

This work was partially funded by the European Union in the context of the Go-Lab project (Grant Agreement no. 317601) under the Information and Communication Technologies (ICT) theme of the 7th Framework Programme for R&D (FP7). This document does not represent the opinion of the European Union, and the European Union is not responsible for any use that might be made of its content.

[1] https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/KK-31-13-401-EN-N.pdf, last accessed: 19/11/2014

- “There are between three and seven students per computer on average in the EU”
- “More than 9 out of ten students are in schools with broadband”
- “No overall relationship was found between high levels of ICT provision and student and teacher confidence, use and attitudes”

The last Europe-wide exercises of the kind reported in the report of the European Commission were the eEurope 2002 and eEurope 2005 surveys, which did not include students directly (ibid. p. 9).

Given the rapid pace of ICT development, findings from one or two years ago might already be (at least to some extent) outdated. One example for this rapid development is that in 2009 the use of ‘learning platforms’ in many UK schools was reported as being in its infancy [5]. A few years later, as reported in the European Commission report for 2011-12, more than one in two (for some countries even more than 90%) grade 8 students were in a school with a virtual learning environment. Additionally the aforementioned report was about ICT in general but not online labs in particular. Earlier surveys did not involve students, one of the two main target groups for online lab usage in schools, directly. Hence, we have been motivated to conduct a new survey. While having the same coverage as the European Commission report was not possible in the scope of the project, by supplementing as well as complementing such existing findings with specific data focusing on software tools and online lab usage, the picture of the current technology-supported STEM education could be sketched with more relevant details.

We found other projects informing teachers about online labs and how to use them at school (e.g. [2]), but they often focus on the actual usage opportunities, not on the possible barriers that might hinder the deployment of online labs.

III. Survey Design and Implementation

To account for the different needs of the two main target groups, namely teachers and students, two questionnaires have been developed with one targeting teachers and their needs and the other one targeting students[2].

A. Demographic data questions

At the beginning of the student questionnaire general demographic data was collected (school level, gender, age, and country of residence). In the teacher questionnaire the respondents were additionally asked about their main teaching topic and for how long they had taught it.

B. Information Technology (IT) infrastructure questions

As IT infrastructure and knowledge is critical for technology use in a classroom, the next section of the survey questionnaires aimed to collect data in this respect. Teachers and students were asked what type of IT infrastructure they mostly use, which operating system, and which web-browser. For teachers those questions were further specified by adding “at school”.

To further investigate whether and what constraints are imposed on the usage of web browsers at schools, the next questions were formulated accordingly.

C. Tools for learning questions

To gather feedback regarding tool usage for learning, the students were asked to indicate their usage of different categories of tools for learning. They should indicate the usage frequency of search engines (e.g. Google, Bing), email (e.g. Gmail, Yahoo), social media (e.g. Wikipedia, blog, Facebook, YouTube), the Microsoft Office suite (e.g. PowerPoint, Word, Excel), and educational software (e.g. games, computer-aided design [CAD]). The given answer options to choose from were ‘never’, ‘infrequent’ (less than 2 hours per week), ‘moderate’ (between 2 and 5 hours per week), and ‘frequent’ (between 5 and 10 hours per week). The students were then asked an open-ended question on their experience with any other software tools that supported their learning. For the teachers the list of tools was more comprehensive and detailed, with additional answer options that enabled them to indicate if they don’t know what this individual tool is and to write a textual comment regarding the frequency option chosen. The list of learning tools the teachers were asked about consisted of document creation and hosting tools, email tools, blogging / Wiki website tools, web conferencing tools, course management systems, social networking platforms, Web (re)search, educational tools, video tools for sharing, and cloud storage tools.

D. Practical experience with online labs in general questions

The second section of the questionnaire contained questions regarding the respondents’ practical experience with online labs. It started with a brief description of remote labs (real equipment which is accessed remotely) and virtual labs (where real equipment is simulated) and their differences, as this distinction was needed to answer some of the following questions. Students and teachers were then asked which types of online labs (remote and / or virtual) they have used and how they would rate their knowledge regarding each type on a 5-point scale (very low, low, medium, high, very high).

E. Practical experience with a particular online lab questions

After these general questions, information about the online lab the students most recently used or the teachers had experience with were collected. They should give the name and if possible link to the online lab, indicate which type (remote or virtual) of lab it is, for which domain it was designed, and how they got to know about it. Although the questions were the same, the answer options for the question on the knowledge source differed slightly between the two groups. For students, the options were: directly through my teacher/lecturer as learning material, web-based search/research, recommendation by parents/friends, from a publication (e.g. science book, magazine, newspaper), and other. For teachers, the options were web-based search/research formal recommendation by an educational authority (e.g. part of syllabus, an expert in a training course), informal recommendation by colleagues/friends, from a publication (e.g. science book, magazine, newspaper), and other. In case the last answer was

[2] The teacher questionnaire can be found here: https://campus.cs.le.ac.uk/go-lab/limesurvey/index.php/978515/lang-en and the student questionnaire can be found here: https://campus.cs.le.ac.uk/go-lab/limesurvey/index.php/797488/lang-en

"web-based search/research" an additional question was asked: how difficult it was to find this lab.

The next set of questions dealt with the lab usage in class by asking in which course the lab was used, for which age group (<10, 10-12, 13-15, 16-18, >18, don't know) it is normally used, in how many lessons it was used, how many minutes each lesson lasted on average and what percentage of a regular lesson / lecture the lab was used (on average). To get information about the involvement of the students, they were asked how they worked with the lab (viewing demonstration only, with no interaction, or practical exercise to do either during the lesson or at home) and how they worked with the lab during the lesson (individually, in group online, in group co-located and / or in group both online and co-located). In the teacher questionnaire the same information was gathered, with slightly rephrased questions where needed.

F. User experience with a particular online lab questions

To gather information about the usability of the lab most recently used by the students or teachers they were asked if they needed help in order to use it, where they got it from (teacher/lecturer/technician, peer, help text, or other), to describe the help commonly sought, and which feature of the lab was most difficult and which one was most enjoyable to use. The next two questions dealt with monitoring, namely to what extent the students were monitored and how important that was for them. The remaining questions in the student questionnaire addressed the user experience of the students when working with the online lab. The first question consisted of nine statements derived from the well-known Technology Acceptance Model (TAM) [6], which are shown in TABLE I. The students were asked to indicate their agreement on each statement with a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

This question was followed by a general question how the students would rate their user experience with this lab (very negative, negative, neutral, positive, very positive). Some more open ended questions were included to gather information about up to three most desirable and undesirable features that contributed to their positive and negative user experience, respectively. Furthermore, in a free text field the students could describe how they would improve the lab so that it could meet their needs and expectations. This section of the questionnaire ended with the question if and why they would recommend the lab to their friends or not (yes, no, don't know), with an option to enter a reason for their response.

For the teacher questionnaire, the same information was collected, using the same, or where needed slightly modified questions (e.g. replacing study with teaching). Only one question was replaced in the teacher questionnaire as compared to the student one: Instead of asking where they did get the help needed, as asked in the student survey, the teachers were asked if they needed support to help their students and where they found it (e.g., asking colleagues, looking up an instruction manual or online help text, consulting the creator of the lab, and other).

TABLE I. STATEMENTS ABOUT WORKING WITH AN ONLINE LAB DERIVED FROM THE TECHNOLOGY ACCEPTANCE MODEL

ID	Statement
S1	I found this online lab useful for my work
S2	I could accomplish my work more effectively with this online lab than with real, physical labs
S3	It was easy for me to use this online lab
S4	It was clear to me how to operate this online lab
S5	I found using this online lab frustrating
S6	Working with this online lab required a lot of thinking
S7	Using this online lab could increase my motivation for learning the topic
S8	Using the online lab could help me to learn the topic by myself
S9	I predict that I will frequently use the online lab when I have access to it

G. Inquiry learning cycle questions

The third section of the teacher survey dealt with the respondents' experience using inquiry learning. This part of the study is not reported here, as it is not related to usability and UX. These results were used by other project partners for the pedagogical shaping of the project's artifacts.

The survey was launched on January 22nd and closed on September 19th 2013. During this time it was accessed by 453 students (primary, secondary, and university level) and 462 teachers. Because not all respondents filled in the whole questionnaire and responded to all the questions, the number of respective responses is indicated in the analysis section.

I. SURVEY RESULTS

A. Demographic data results

Most of the student replies (see TABLE II) came from secondary school students and undergraduate university students, with only a few responses from primary school students and two others. As shown in TABLE III, most student respondents were 13 and above, with a considerably lower number of respondents aged up to twelve, which is expected when looking at the school type distribution. With 51% (male) to 49% (female) the gender distribution (N=339) of the respondents was nearly equal. Regarding the origin of the student respondents (N=360), most stated Spain as their country of residence (21.4%). The complete country distribution of the students can be seen in Fig. 1.

Regarding school types of teachers, as displayed in TABLE IV, most respondents were secondary school teachers and primary school teachers, followed by university teaching staff. Input from the teacher perspective came additionally from other sources, like a vocational school teacher. The age distribution is shown in TABLE V, indicating that the majority of teachers was 36-45 years old. With 49% (male) to 51% (female) the gender distribution (N=330) of the respondents was nearly equal. Regarding the origin of the teacher respondents (N=330), most stated Estonia or Portugal (both 14.9%) or Cyprus or Spain (both 13.0%) as their country of residence. The complete country distribution of the teachers can be seen in Fig. 2.

TABLE II. STUDENT LEVEL (STUDENTS)

	N=339			
	Secondary school student	***University undergraduate***	***Primary school student***	***Others***
Number of replies	192	108	37	2
Percentage of replies	56.6%	31.9%	10.9%	0.06%

TABLE III. AGE DISTRIBUTION (STUDENTS)

	N=339				
	<10	***10-12***	***13-15***	***16-18***	***>18***
Number of replies	3	23	109	100	104
Percentage of replies	0.9%	6.8%	32.2%	29.5%	30.7%

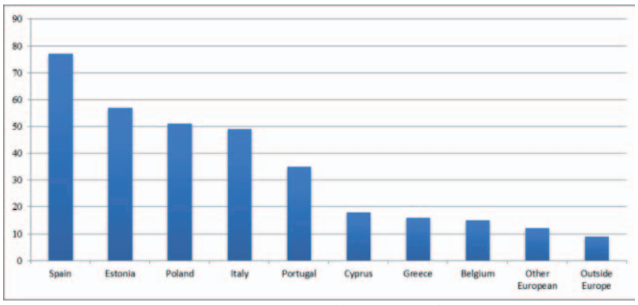

Fig. 1. Country Distribution (students)

TABLE IV. SCHOOL TYPE (TEACHERS)

(N=333)	Secondary school	Primary school	University teaching staff	Others
Number of replies	204	49	29	51
Percentage of replies	61.3%	14.7%	8.7%	15.3%

TABLE V. AGE DISTRIBUTION (TEACHERS)

(N=239)	<26	26-35	36-45	46-55	>55
Number of replies	28	77	108	66	50
Percentage of replies	8.51%	23.4%	32.8%	20.1%	15.2%

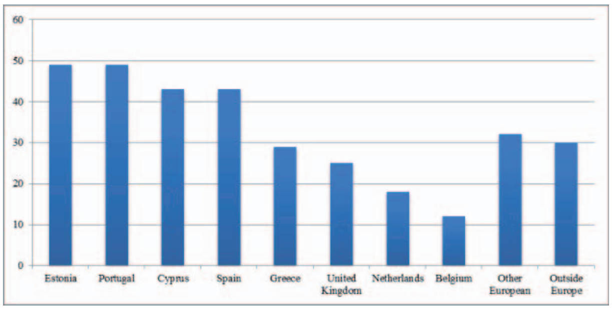

Fig. 2. Country Distribution (teachers)

B. *Information Technology (IT) infrastructure results*

The most common IT infrastructure used by the student respondents (N=235) is PC (39.2%) or laptop (38.7%). But still roughly a sixth reported a mobile phone (17.0%) as their mostly used type of IT used. For only 5.1% of the surveyed students a tablet is their mostly used IT device. The vast majority of the students (N=235) mostly use Microsoft Windows (91.1%) as their operating system, followed by Mac (5.5%) and Linux (3.4%). Regarding the browser the students (N=239) are using, Google Chrome (60.7%) is most prevalent, followed by Mozilla Firefox (20.5%) and Internet Explorer (11.7%). Safari (5.0%) and Opera (2.0%) are less common. Regarding the restriction of browser usage at school, for nearly half of the students (N=239) only a specific web-browser(s) can be used (48.5%), while the other half (51.5%) does not have such a constraint. The other restrictions queried are far less notable, with a specific version(s) of the web-browser being a constraint for 9.6%, therefore 90.4% of the students are unrestricted in this regard, and only a certain plug-in(s) can be used being the case for 16.3%.

For the teachers (N=197) the distribution of laptop (64.0%) and PC (25.9%) is not as even as for the students, with laptop being far more common. As with the students, tablet (5.0%) and mobile phone (2.0%) were only given as a response by a minority of teachers. The vast majority of teachers (N=197) mostly use Microsoft Windows (86.3%), followed by Mac (9.6%) and Linux (2.5%). Regarding the browser the teachers (N=197) use, Google Chrome (44.2%) is most prevalent, followed by Mozilla Firefox (28.9%) and Internet Explorer (22.3%). Safari (4.1%) and Opera (0.5%) are again less common. Regarding the restriction of browser usage for teaching purposes, about a third of the teachers (N=197) can only use a specific web-browser(s) (35.5%), while nearly two third (64.5%) do not have such a constraint. Similar to the student distribution regarding version restriction, 11.2% of the teachers can only use a specific version(s) of a web-browser, leaving 88.8% of the teachers unrestricted in this regard. Only being able to use certain plug-in(s) is the case for 20.8%.

C. *Tools for learning results*

The students' responses regarding tools used to support their learning are displayed in Fig. 3, which shows that social media and search engines are the tools most frequently used. Educational software is used least frequently.

The teacher responses regarding tools used to support teaching displayed in Fig. 4 also show that search engines are most and educational tools least frequently used.

D. *Practical experience with online labs in general results*

Of the students who reported to have experience with online labs (N=298), a fifth (20%) had experience with both types of labs and the rest nearly equally experienced either only remote labs (38%) or only virtual labs (42%). The level of experience they reported for remote or virtual labs was mostly medium, followed by low, very low, high, and very high, as reported in TABLE VI.

Of the teachers that reported to already have experience with online labs (N=268), a fourth (26%) had experience with both types of labs. More than half of the teachers had only experience with virtual labs (54%) and the remaining fifth (20%) only with remote labs. The level of experience they reported for remote or virtual labs was accordingly higher for virtual labs than remote ones (cf. TABLE VII).

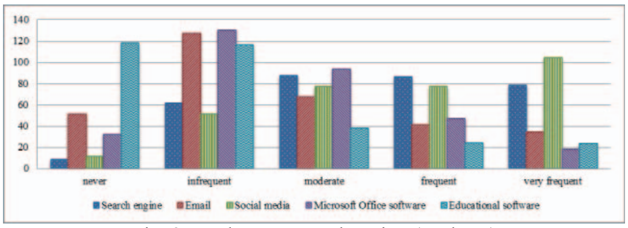

Fig. 3. Tools to support learning (students)

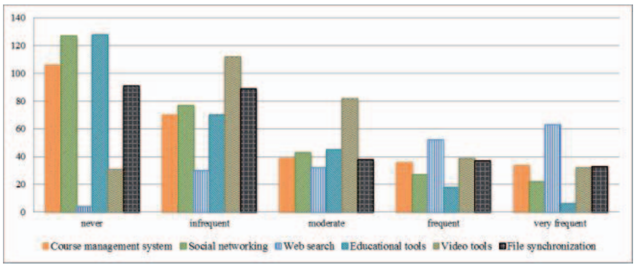

Fig. 4. Tools to support teaching (teachers)

TABLE VI. LEVEL OF EXPERIENCE WITH ONLINE LABS (STUDENTS)

	students' level of experience				
	very low	*low*	*medium*	*high*	*very high*
remote labs (N=172)					
Number of replies	34	51	67	15	2
Percentage of replies	19.8%	29.7%	39.0%	8.7%	2.9%
virtual labs (N=185)					
Number of replies	33	48	76	22	6
Percentage of replies	17.8%	26.0%	41.1%	11.9%	3.2%

TABLE VII. LEVEL OF EXPERIENCE WITH ONLINE LABS (TEACHERS)

	teachers' level of experience				
	very low	*low*	*medium*	*high*	*very high*
remote labs (N=115)					
Number of replies	31	35	30	15	4
Percentage of replies	30.0%	30.4%	26.1%	13.0%	3.5%
virtual labs (N=185)					
Number of replies	48	46	62	38	9
Percentage of replies	23.7%	22.7%	30.5%	18.7%	4.4%

E. Practical experience with a particular online lab results

Of the students specifying a particular online lab (N=237), nearly a half used the most mentioned lab, WebLab Deusto (http://www.weblab.deusto.es/website/, 44.3%), followed by PhET Interactive Simulations (http://phet.colorado.edu/, 11.0%), "Loodusteaduslikud mudelid põhikoolis" (Scientific models in basic school, http://mudelid.5dvision.ee/, 8.9%), and HYPATIA (http://hypatia.phys.uoa.gr/, 8.0%). The vast majority of students (N=194) learned directly from their teacher about the online lab (90.7%). As the other questions in this set of questions rather deal with correctly identifying the type and domain of the used lab, their results are not further reported here.

The teachers (N=176) used a wider variety of different labs than the students. The three most commonly mentioned labs are PhET Interactive Simulations (21.0%), Faulkes Telescope (http://www.faulkes-telescope.com/, 14.8%), and WebLab Deusto (7.4%). Again, the results of the related questions are not reported in this paper. The answers regarding the source from which the teachers (N=206) learned about the online labs were nearly equally distributed over the first three answer options (Formal recommendation by an educational authority: 28.2%, Web-based search/research: 27.2%, Informal recommendation by colleagues/friends: 24.8%), only a few found them from a publication (4.4%). For the teachers searching for labs this task seemed to be rather easy (average rating of difficulty to find was 26.2 out of 100, with a standard deviation of 24.7).

The results on the usage of online labs in lessons, displayed in TABLE **VIII**, show a significant difference between (primary and secondary) school and undergraduate university students.

Similar to the results from the student survey the usage of online labs in lessons varies a lot between the different teachers, as can be seen in TABLE **IX**.

For 50.4% of the students (N=264) the online lab was used to let them perform a practical exercise during the lesson, while 30.3% only viewed a demonstration, and 11.0% did a practical exercise with it at home. The majority of students used the lab individually and not in groups.

The teacher (N=174) responses on the ways of using the online lab were similar to those of the students. Most (43.7%) let students perform practical exercises during the lesson. As for the students, demonstrating was the second most chosen option (24.7%) and 10.9% used it to let the students do practical exercises at home. The percentage values for the predefined answers are a little bit lower than for the students as teachers had more "other" (20.7%) reasons to use the lab as the students, e.g. to familiarize themselves with the lab before using it with their students.

F. User experience with a particular online lab results

As one aspect of the usability of existing labs, students were asked how much help they needed. They (N=215) reported a medium amount of help needed (39.6 out of 100 with standard deviation of 31.7), provided by their (N=213) teacher/lecturer/technician (76.1%), peers (15.5%) such as classmates and friends, help text (7.0%), or other sources (1.4%) such as Google. The help most commonly thought by the students (N=67) was regarding the use of the lab (61.2%) and theoretical advice (13.4%), followed by language, task understanding, and technical issues (all three 6.0%). Finding a lab (4.5%) and login or installation (3.0%) were additional issues students reported as reasons to search for help. The features most often reported as most difficult were the (English) language and experiment setup (mentioned equally often by 16.2% of N=74), the feature reported as most enjoyable was the experimentation (22.2% of N=81).

TABLE VIII. NUMBER OF LESSONS AND THEIR DURATION, WITH THE AMOUNT OF LESSON USED FOR THE ONLINE LAB (IN %), REPORTED BY THE STUDENTS.

	Primary and secondary students			University undergraduate students		
	No. of lessons	*Min. per lesson*	*% of lesson*	*No. of lessons*	*Min. per lesson*	*% of lesson*
Average	2.1	38.1	40.5	11.8	94.3	58.2
SD	1.4	20.5	30.5	16.0	129.4	26.1
Median	2	40	32	3	60	55

TABLE IX. NUMBER OF LESSONS AND THEIR DURATION, WITH THE AMOUNT OF LESSON USED FOR THE ONLINE LAB (IN %), REPORTED BY THE TEACHERS.

	Teacher respondents		
	No. of lessons (N=175)	*Min. per lesson (N=157)*	*% of lesson (N=95)*
Average	18.8	46.9	49.3
SD	80.2	46.3	30.0
Median	5	45	50

The teachers (N=169) reported a similar amount of help thought by the students as the students did in the student survey (38.1 out of 100 with standard deviation of 28.8). They (N=169) mostly (57.4%) did not need support to help their students. Of those that did, 37.5% used the manual or online help, 23.6% asked a colleague and 18.1% consulted the lab creator, while the remaining 20.8% used other sources of help, like training they obtained.

As the monitoring questions are mainly of interest from a pedagogic perspective and not so much from a usability point of view, their results are not reported in this paper.

TABLE **X** shows the students (dis)agreement to the different statements about online labs, giving more detailed information regarding different user experience aspects and how the students perceived them. The reported overall UX of the students is accordingly mostly (very) positive, with a third reporting a neutral experience and only an eighths (very) negative (cf. TABLE **XI**). The students used the free text fields of the next questions to describe some desirable (e.g. ease of use of online labs and choice of experiments or objects) and undesirable features, like the instructions of the lab being in English and not in their native language. Going into detail would be out of scope of this paper, but some valuable insights could be gathered here. Consequently "translation" was the general improvement suggestion given the most. The final question regarding recommendation to their friends revealed even slightly more positive results than the one regarding the user experience: 61.3% of the students (N=248) would recommend it to their friends and only an eighths (12.5%) would not. The rest (26.2%) was not sure if to recommend it or not ("don't know").

TABLE **X** shows the teachers (dis)agreement to different statements about online labs, again giving a more detailed picture than just an overall UX rating. The perceived user experience of the teachers is even more (very) positive (83.6%) than those of the students, with a seventh reporting a neutral experience and only a few a negative one. As can also be seen in TABLE **XI** no teacher reported a very negative user experience. The final question (as the section about the inquiry learning circle is not analyzed in this paper) regarding recommendation to others revealed that the vast majority (89.8%) of the teachers (N=157) would recommend the used online lab to others, where 7.6% where not sure ("don't know"), and only a few teachers would not recommend it (2.5%).

TABLE X. STUDENT (ST) AND TEACHER (T) AGREEMENT TO THE STATEMENTS (REFERENCED USING THEIR ID) IN TABLE I

ID	Strongly disagree		Disagree		Neutral		Agree		Strongly Agree	
	St	*T*	*St*	*T*	*St*	*T*	*St*	*T*	*St*	*T*
S1	34	11	36	8	67	31	76	47	43	66
S2	36	17	42	28	102	48	49	40	26	30
S3	31	15	34	9	52	36	59	45	79	58
S4	32	15	42	14	78	29	70	48	32	57
S5	102	98	63	29	43	25	26	8	20	3
S6	74	49	74	51	49	44	43	12	14	7
S7	33	15	30	6	84	38	68	71	39	33
S8	31	16	25	14	92	45	70	55	36	33
S9	41	14	47	13	68	42	66	45	32	49

TABLE XI. USER EXPERIENCE WITH ONLINE LAB (STUDENTS AND TEACHERS)

N=249 (students) N=159 (teachers)	very negative	negative	neutral	positive	very positive
Student replies	5.2%	7.2%	32.1%	45.8%	9.6%
Teacher replies	0.0%	1.9%	14.5%	47.8%	35.8%

I. FINDINGS

A. *Information Technology (IT) infrastructure and tools for learning findings*

PCs and laptops with Microsoft Windows as operating system are still the major IT devices used by students and teachers, although tablets and mobile phones become more and more common in non-school use-cases. To ensure positive user experience for the majority of users the web-portal to be used in science lessons should therefore be optimized for usage with a computer. Compatibility with tablets and mobile phones would be nice to have as this would appease those in the target group using those devices.

Regarding browser compatibility of the online components to be developed the results show that although Google Chrome is most prevalent for students and teachers, all three major browsers are used by a considerable number of respondents. Therefore the development team needs to consider browser-compatibility and develop for all three major browsers. In other words, one cannot focus on a particular browser. From a usability perspective that will ensure the same or at least equally good user experience of the students and teachers, regardless of which browser they prefer to use (or have installed at school). At the same time the developers cannot assume that this will always be the most recent version of the browser, thus they might have to do without the most recent functionality, which might not be supported by previous versions of browser, still in use at schools.

When developing a web-portal for use in schools, the restrictions regarding browser usage in schools need to be taken into account. Although we would have expected even more and harder constraints in school environments, the analysis of our questionnaires shows that there are fewer restrictions than expected, but they would still disturb the portal usage if not considered. Being only able to use a specific browser (and sometimes only specific versions of it with only certain plug-in(s)), puts constraints on the development work.

Educational software being the least used of the tools for learning shows, that there is still a big potential for software tools and online labs to be used in STEM education.

B. *Practical experience with online labs in general findings*

As variety might make working and learning with online labs more interesting, the target group should be exposed to different types of online labs, as the results show that the majority of them currently only knows about one type of lab. But as diversity is only one of the factors when deciding on the type of online lab to use (e.g., the type must fit the content and an online lab of this type must be available for this topic), additional factors need to be considered when attempting to expose more students and teachers to different lab types.

The results regarding the level of experience with online labs show a mainly medium to low level of experience. This corresponds with the results of a rather low usage of educational software. This again shows that there is an unexhausted potential of online lab usage in STEM education, which would lead to a higher level of experience.

C. *Practical experience with a particular online lab findings*

From a user experience perspective we see improvement potential for the use of software tools and online labs in STEM education by easing the process of searching and finding appropriate tools and labs. From the survey results one can see that although nearly two thirds of the used labs were recommended to the teachers still about a third was searched for by the teachers themselves. Although the results regarding the difficulty of finding labs using online search indicate that the teachers did not find it too difficult, there is still potential for improvement. To support the teachers in both tasks (searching appropriate labs and discovering online labs), one goal of the Go-Lab project is to develop a repository of online tools and labs (www.golabz.eu). This would give teachers a single starting point for their search (compared to the whole Internet) to make searching and discovering new labs easier. At the same time this repository incorporates additional support mechanisms beyond keyword search (e.g. clustering by topic) to offer additional value compared to searching with an Internet search engine.

As the usage results displayed in TABLE **VIII** and TABLE **IX** show, online labs are currently not used on a daily basis and have a relatively short exposure time to the students overall. From a usability perspective this implies that the learnability of the online labs needs to be high, i.e., students need to be able to quickly learn to interact with the labs so that they can spend time on learning the science topic, not how to use the graphical user interface.

According to the results on the way the online lab was used it can be seen that nearly two third of the students actually interacted with the online lab themselves, where a third watched the teacher demonstrate something. From a UX perspective this means that the usability of the online lab must not only be sufficient for teachers but also for students. That needs to be considered when evaluating and selecting existing labs to add to the Go-Lab repository.

D. *User experience with a particular online lab results*

As the teachers were the main source of help when needed and they were able to mostly help their students without needing additional help themselves, it seems that the interaction with existing online labs is mostly intuitive enough for the students (although the help most commonly thought was about the use of the lab) or at least for the teachers to advise their students in case of issues.

When using existing software tools and online labs in STEM education and designing a portal for use in schools all over Europe an important (usability) barrier to tackle seems to be the language. Having all the resources and interfaces in English seems not sufficient for the target group of students, as the (English) language was reported as one of the most difficult features. Although the experiment setup was the second big issue reported as difficulty besides the language, the actual experimentation was reported as being the most enjoyable experience. Still the lesson learned from here could be that the experiment setup needs to be considered especially when designing and evaluating online labs.

The results of the general user experience rating of the students and teachers and their readiness to recommend it to their peers show that the users who used online labs enjoyed the experience. This is encouraging to bring more "virtual learning" to the field of STEM education to allow more people to have the same positive user experience.

II. THREATS OF VALIDITY

A. *Representativeness*

The school and correspondingly age distribution of students is not equally between different school types. The same is true for the school type distribution of the teachers. Therefore, when interpreting the results it has to be kept in mind that the findings are mostly relevant to older students rather than to primary school ones.

The remaining demographic results (e.g. age distribution of teachers) also show a possible bias in the dataset: it might not be representative for the whole target group and the whole of Europe (only the gender distribution of students and teachers is nearly equal). For instance, the country distribution of the survey responses is not even between the European countries. This can be attributed to the fact that the survey has been distributed by the project partners in their existing networks, which are not necessarily evenly spread across Europe and target groups (e.g. from the responses it can be seen that there is a strong network in Spain). The survey results still give an overview about the current use of software tools and online labs in STEM education, when looking at the results one just have to keep in mind that they may not be representative for the whole of Europe. It still serves the purpose of getting a general impression.

Also from the possible range of online labs, the results of this survey might not be representative, as e.g. nearly half of the student responses regarding a particular online lab are about one specific lab (WebLab Deusto). But as the rest of the student results and the teacher results are more diverse, this could make up for this fact. Still it needs to be kept in mind when interpreting the results.

B. *Questionnaire design and distribution*

Analyzing the results shows quite a number of only partially filled in questionnaires. This can be explained at least partly with the fact that not all respondents had experience with online labs, causing them to skip the second section of the questionnaire. The lesson learned from this for future surveys is to first present a question asking if the participant has experience with online labs or not and based on this answer either to display the online lab related questions or the end screen, being classified as "full" response questionnaires even when skipping part of it. For the analysis of the current dataset this has been addressed by using the appropriate amount of total number of responses to this question, when working with and analyzing the feedback.

As the goal of this questionnaire from the project perspective was to gather information about current online lab usage, it was distributed to respondents who were thought or at least more likely to have experience with online labs. The amount of lab usage might be influenced by this sampling bias, resulting in a higher result than with a random sample. If this should be the case, this would even further support the assumption that online lab usage is not very common at the moment and thus STEM education could greatly benefit from more online lab inclusion.

III. Conclusion and Future Work

Although the results presented in this paper are not necessarily representative for Europe, the entire target group of students and teachers, and the range of existing online labs available, they give an interesting first impression about current software tool and online lab usage. Further surveys, based on the current questionnaire with some improvements to overcome the shortcomings detected, with a larger and more diverse base of respondents should be conducted to collect additional data and strengthen (or maybe change) this first impression.

Some of the findings presented in this paper were expected when designing the questionnaire. Examples for such data are the IT infrastructure usage with the vast majority of respondents using PCs or laptops with Microsoft Windows as operating system and one of the three major browsers to access Internet resources. The survey was here merely used to back up the existing assumptions. Other findings were less expected or rather surprising such as the restrictions regarding browser usage in schools, which were not as strict as assumed (but still common enough that they still need to be considered by developers). Here the survey could shed some light on the current usage of software tools and online labs in schools and provide some valuable new insights. Again further surveys and longer-term observations should be conducted to validate if there is a trend and if it continues, which would mean that in some years from now, this constraint could be gone.

As students and teachers report a positive user experience when using online labs they seem to be a desirable way to learn about and teach science topics in school. But their appropriateness also needs to be checked from other viewpoints as well (e.g. from the pedagogical perspective to assure that the learning outcome is good enough as well). Therefore additional testing of online lab usage in classroom settings needs to be performed and combined with the results presented in this paper to get an overall picture.

Several findings (e.g. rare usage of educational software and low level of experience with online labs) show that online labs are not yet widely used in STEM education. At the same time those who actually used them report it as a positive experience and the majority of them would recommend it to others. Although some of the online lab users had to overcome the obstacle of setting up experiments, the experiment itself was reported as enjoyable. This can be seen as evidence that the goal of the Go-Lab project to enhance online lab usage in education is valid (at least from a user experience point of view) and should be further pursued. To attain this goal, the critical approach is to ease the access to online labs by collecting existing resources in a repository and by providing teachers with facilities to create enjoyable learning experience around an online lab.

This collection of different online labs would also help to provide a broader variety of options (e.g. lab type) to choose from, which would allow for variation in experiments and could therefore encourage the users to utilize different online labs in different ways.

Although English is commonly used as kind of a "universal" language in several contexts such as the research community, this seems insufficient for resources to be used in the European STEM education, as students from non-English-speaking countries struggle with English instructions and content.

To ensure that the online labs to be included in the project's repository (i.e., the Go-Lab Portal), and other software applications developed in the project have high usability and deliver positive user experience, participatory design (PD) is adopted. Specifically, PD involves users (i.e., in our case, teachers and students) in the development process from the outset of the project till its end, eliciting users' feedback and incorporating it to improve iteratively the system being designed and developed for them.

Here we revisit the two RQs presented earlier. For RQ1, the findings indicate that although most of the existing online labs are suited for the use in classroom and are perceived as providing positive experience by teachers and students, the use of online labs is not widespread and common. The survey conducted confirmed some assumptions regarding the usage of software tools and online labs while it also provided some helpful insights through unexpected results, which both will be used to improve the software components and websites to be developed in the Go-Lab project, but should also be interesting for other researchers working in the field of software-supported STEM education.

For RQ2 the existing software tools and online labs used and assessed by the students and teachers participating in this survey are rated as having a positive user experience, thus looking at them can give designers and developers some good insight into what the diverse target groups want and need.

These findings can not only benefit the Go-Lab project but also researchers and practitioners working in this area of STEM education.

ACKNOWLEDGMENT

We want to thank all Go-Lab partners who contributed to the creation and distribution of the surveys.

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