R.1.2 Missing components/elements/services to enable interconnection identified

for the Project Education 4.0: Living Labs for the Students of the Future (LLSF)
Contract number 2021-1-RO01-KA220-HED-000032176

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List of participants

Participant No *	Participant organisation name	Acronym	Country
1 (Coordinator)	University POLITEHNICA of Bucharest	UPB	RO
2	Universidade NOVA de Lisboa	NOVA	PT
3	Universita Politecnica delle Marche	UPM	IT
4	Universidad Nacional de Education a Distancia	UNED	ES
5	Tel Aviv University	TAU	IL

Revision history:

Rev	Date	Partner	Description	Name
1	6/Apr/2022	UPB	First draft	Ciprian Dobre
2	20/Apr/2022	UPB	Final draft	Ciprian Dobre

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Contents

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Scientific and technical report on A.1.
Analysis of existing digital HW/SW products and services that will be included in the smart labs and of missing elements to enable their interconnection

Objective: IO1
Internet of Things and Data Engineering Training Methodological Toolkit
(eLearning smart digital labs)

1. Introduction

The pandemic has utterly disrupted an education system that many assert was already losing its relevance. Today education focuses on memorization and standardization, but the future should mix a blend of intelligence, emotional intelligence, and resilience. We believe a new hybrid model of education emerges nowadays, with significant benefits. There is evidence that online learning can be effective, as research shows that, on average, students retain[1] 25-60% more material when learning online compared to only[2] 8-10% in a classroom. In online, students can learn at their own pace, going back and re-reading, skipping, or accelerating through concepts as they choose.

Education 4.0 is a mix between learning, where online lectures are complemented with self-paced online practice activities, and science, where students are co-designer and co-creators of new knowledge. Laboratories are main generators of both education and innovation capabilities. By transforming labs to become digitally enabled, globally connected powerhouses capable of breakthrough innovation at scale, we believe to be able to turn the tide of innovation and future education capabilities. The big challenge? Navigating oceans of information. An unprecedented number of experiments are being explored today in many science domains. Innovations, while incredibly exciting, have also exposed a fundamental weakness in laboratory operations: the collective inability to harness the power of the oceans of data we generate. The LLSF project proposes, thus, to adopt an end-to-end data strategy and then execute against it: connecting data from disparate sources like labs, collaborators, and the real world to generate insights. Or, in other words, connected data is key to transformation.

Just to give a summary, in this Deliverable we are presenting our conclusions following an analysis of the potential for **existing digital HW/SW products and services that will be included in the smart labs and of missing elements to enable their interconnection**.

[1] https://www.shiftelearning.com/blog/bid/301248/15-facts-and-stats-that-reveal-the-power-of-elearning
[2] https://techjury.net/stats-about/elearning/#gref

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2. Analysis of existing digital HW/SW products in partner infrastructure

For the analysis, we started with the introduction of a Questionnaire for collecting data from all partners. The questionnaire includes 25 questions:

No.	Question	Choices
I. Learning survey about your students' activity		
1.	Does your institution combine online and offline learning activities? By online activities we mean, for example, assisting students in learning with tools and instruments they can use on their own, like an online simulation instrument, a virtual machine for running code, etc.	Yes/No
2.	Is your institution interested in giving students the possibility to self-pace competence development using online tools?	Yes/No
3.	In the post-pandemic times, do your students still have access and use an electronic device for learning online in virtual classes?	• Yes, daily • Yes, sporadically or it doesn't work well • No, they share with others
4.	What type of devices are used by your students? Choose the most used 2 devices.	• SmartPhones • Tables • Laptops • Desktops • Other...
5.	In your experience, how do your students feel overall about distance education? Consider the benefits when asking them, like the fact that they can learn in their own style and pace the curricula.	• Excellent • Good • Average • Below Average • Poor
6.	If your institution offers online activities, how much time do your students spend each day on an average on distance education?	• 1-3 hours • 3-5 hours • 5-7 hours • 7+ hours
7.	In your experience, how effective was remote learning been for your students compared to other means of teaching?	• Extremely effective • Very effective • Moderately effective • Slightly effective • Not at all effective
8.	How helpful your School or University has been in offering your students the resources to virtually learn?	• Extremely effective • Very effective

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		• Moderately effective • Slightly effective • Not at all effective
9.	Understand Student Engagement in Virtual Learning by professor evaluation. 1. How excited are your students about going to virtual classes? 2. How often do your students get so focused on activities in virtual classes that you lose track of time? 3. In your classes, how eager are your students to participate? 4. When you are not in school, how often do your students talk about ideas from virtual classes? 5. Overall, how interested are your students in virtual classes? 6. How difficult or easy is it for your students to connect to the internet to access your schoolwork?	1 - lower score / 5 - higher score
10.	In your experience, what are the most engaging activities that happen in an online-based class?	Free answer
11.	Which aspects of such a class did you find least engaging?	Free answer
12.	If you would teach an online-based class, what is the one thing you think would make it more engaging for students?	Free answer
13.	How do you know when you feel engaged in class?	Free answer
14.	What projects/assignments/activities do your students find most engaging in this type of class?	Free answer
15.	What has been the hardest part about completing virtual schoolwork?	Free answer
II. Learning survey about professors' activity		
16.	Do you enjoy learning remotely?	• Yes, absolutely • Yes, but I would like to change a few things • No, there are quite a few challenges • No, not at all
17.	What technology/devices do you use for virtual classes (the most used 3 technologies).	• Laptops/tables/smartphones • Smart boards / Interactive boards • Video materials / animations • Slides • Offline materials (books, notes, others) • Virtual Reality tools

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		• Avatars • Other...
18.	How many classes (on average) do you and your colleagues teach in a physical way per week.	1 / 2 / 3 / 4 / Other
19.	How many classes (on average) do you and your colleagues teach in a virtual way per week.	1 / 2 / 3 / 4 / Other
20.	What technologies do you know to be used for student class management? (click all that apply)	• Moodle • Canvas LMS • Google Classroom • Blackboard Learn • TalentLMS • D2L Brightspace • Schoology • Edmodo • Sakai • mindclass.eu • Thinkific • Teachable • LearnDash • OpenEdX
21.	What technologies do your institution use for student class management? (select all that apply)	• Moodle • Canvas LMS • Google Classroom • Blackboard Learn • TalentLMS • D2L Brightspace • Schoology • Edmodo • Sakai • mindclass.eu • Thinkific • Teachable • LearnDash • OpenEdX
22.	Have you heard about EduGain before?	Yes / No
23.	Do you know about the Jupyter notebook solution for the virtual class laboratory?	Yes / No
24.	How many use-cases implemented in the Jupyter notebook do you know/have?	0 / 1 / 2 / 3 / 4+
25.	How many students do you have, in average, in virtual classes?	10 / 20 / 30 / 40 / 50+
III. Personal Information		
26.	Your institution:	Free text

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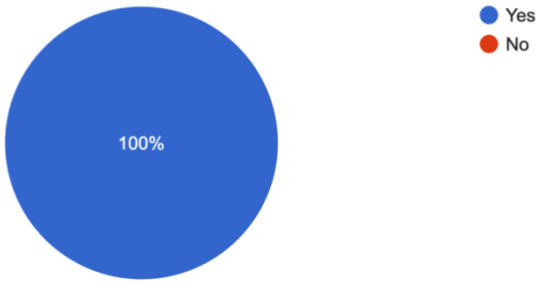
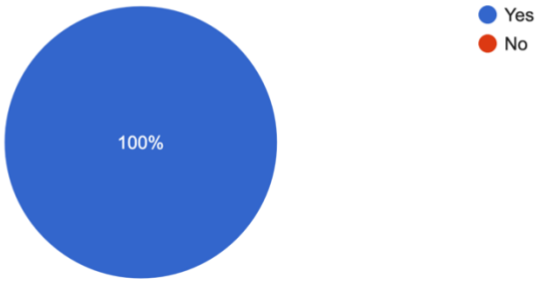
27.	Your current academic/scientific possition:	Free text

The questionnaire was completed by all partners in the project. A total of 12 responses were collected. The answers are as follows:

No	Answer
I. Learning survey about your students' activity	
1.	Does your institution combine online and offline learning activities? By online activities we mean, for example, assisting students in learning with to...nstrument, a virtual machine for running code, etc. 12 responses 
2.	Is your institution interested in giving students the possibility to self-pace competence development using online tools? 12 responses 

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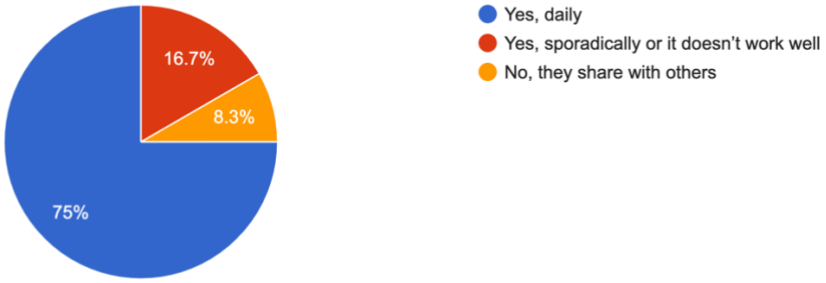
3.

In the post-pandemic times, do your students still have access and use an electronic device for learning online in virtual classes?

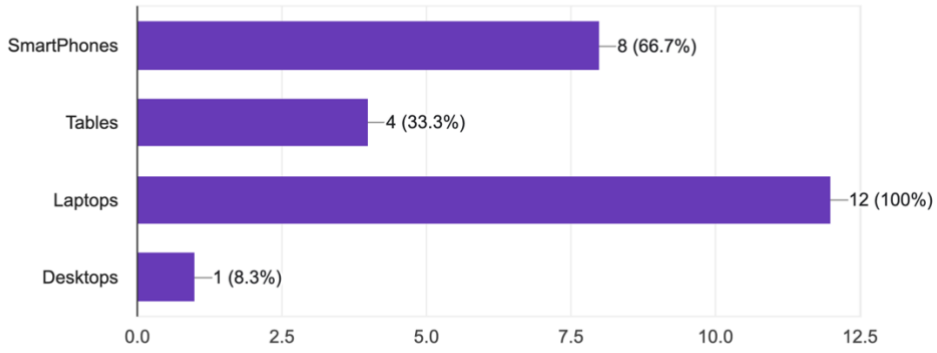
12 responses



4.

What type of devices are used by your students? Choose the most used 2 devices.

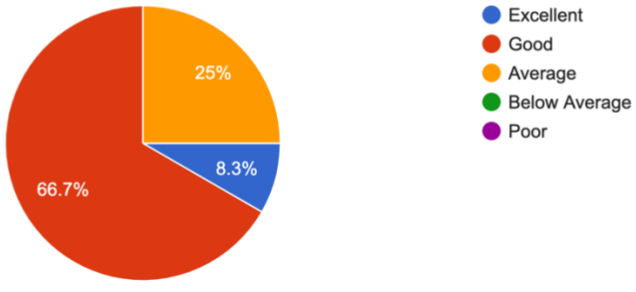
12 responses



5.

In your experience, how do your students feel overall about distance education? Consider the benefits when asking them, like the fact that they can learn in their own style and pace the curricula.

12 responses



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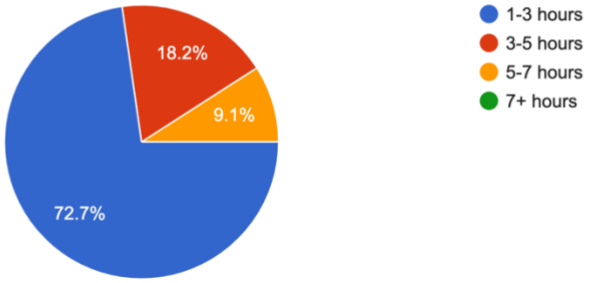
6.

If your institution offer online activities, how much time do your students spend each day on an average on distance education?

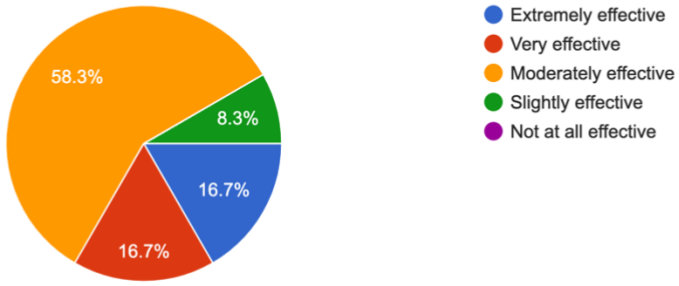
11 responses



7.

In your experience, how effective was remote learning been for your students compared to other means of teaching?

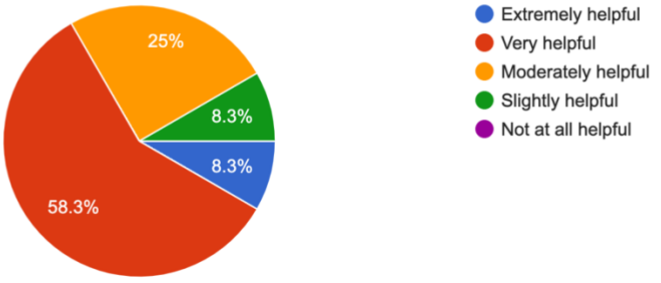
12 responses



8.

How helpful your School or University has been in offering your students the resources to virtually learn?

12 responses



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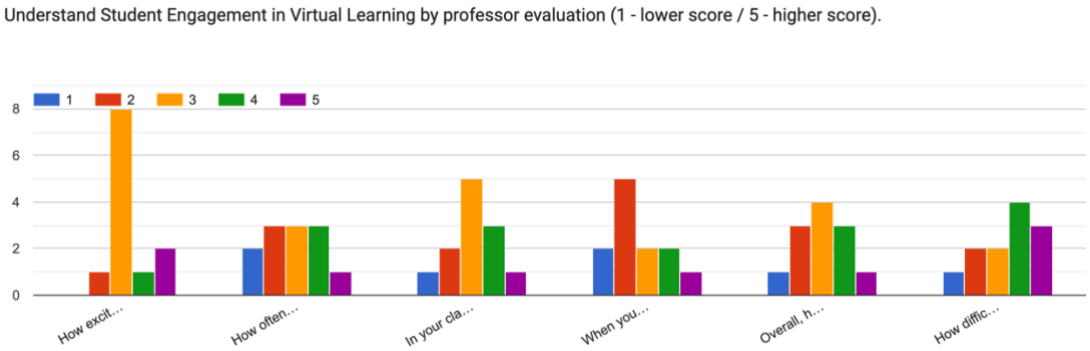
9.	
10.	*In your experience, what are the most engaging activities that happen in an online-based class?* • Activities that involve students in ordert to solve a problem (e.g. laboratories / seminars / projects development). • The fact that students can see live coding, can share a screen or an editor (of documents or even of code) and that the overall experience seems more hands-on. • Real-time and shared use of software tools for example to show how a piece of code works • Webminars • Practice exercise • not a particular one • Practice exercises, demos, short tests, short evaluation questionaries. • Task resolution • Solve questions and problems.
11.	*Which aspects of such a class did you find least engaging?* • Course teaching without students' interaction is the least engaging activity for students. • There is less of an interpersonal relationship, especially when video is not available. • Teaching online does not provide visual contact with students who typically keep their cameras closed. • The lack of feedback from students. • Students interaction • when classes are big there are problems concerns • Students interaction between them and with teacher, imediate feedback for practical exercises. • Theoretical slides • Presentations with a lot of text.

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12.	*If you would teach an online-based class, what is the one thing you think would make it more engaging for students?* • Students must be actively involved in order to stimulate them (e.g. quiz, live demonstration with students involvement). • Try to make everyone be more involved by turning on their cameras, having contributions, and working in teams. • Dialog • The possibility to interact remotely with physical objects such as instruments or sensors • Teachers MUST learn how to properly perform on online-based classes, otherwise students get bored and just silence lecture. • Mutual collaboration. • The possibility of using laboratory equipments • have a board a camera to teach as everyone was with me in a traditional class room • The possibility of using laboratories in real time for making measurements and experiments. • Collaboration, dialog, self evaluation. • Exercises • Active participation activities
13.	*How do you know when you feel engaged in class?* • When your attention is focused on the respective class. • There is a lot of talking (in a positive sense), constructive discussions, collaboration and eagerness to finish tasks and show it. • From the questions I get from students and if there is any discussion on what I present them • When I receive feedback from students or when the put some questions or stop my by the coffee machine to have further information. • if the students have questions during the lesson • by the level of interactions • The students makes questions during the lesson. • Students questions during the classes. • Lots of responses • The make questions.
14.	*What projects/assignments/activities do your students find most engaging in this type of class?* • Virtual laboratories, projects with real implementation. • Online coding problems or quizzes (such as Kahoot, for example).

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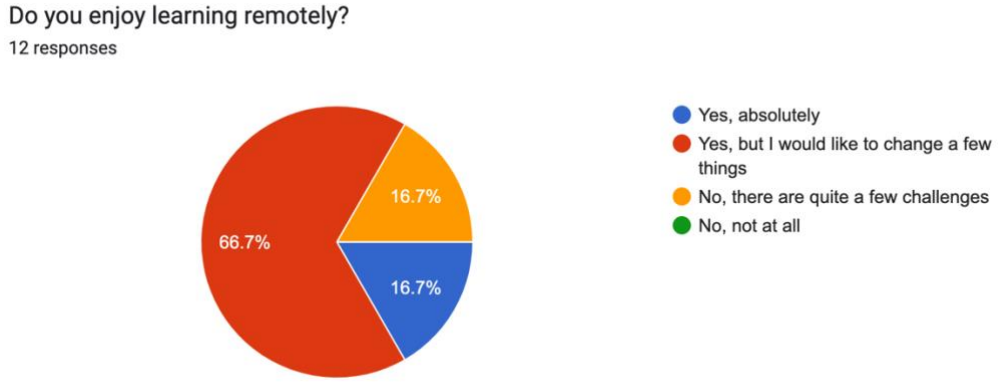
	• Trying to show them real devices with a steady-cam. • Practical activities • interactive activities or exercises • Quizzes, online coding, self-testing of their practical exercises. • exercices • Solve problems and questions.
15.	*What has been the hardest part about completing virtual schoolwork?* • Making most of the students understand the content of each class. • The reduced level of interaction with the students (at least occasionally). • Attention of students • Trying to prepare some kind of experiments students could perform remotely • n/a • Having from the students individual contributions: most students are apparently passive. • Knowing if the students have achieved good results • check they are. paying attention • The absence of feedback from other people.
II. Learning survey about professors' activity	
16.	

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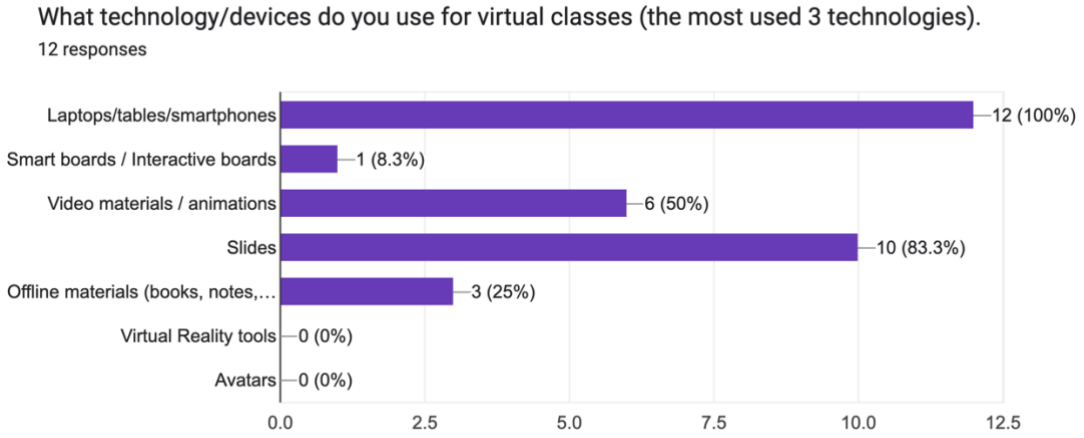

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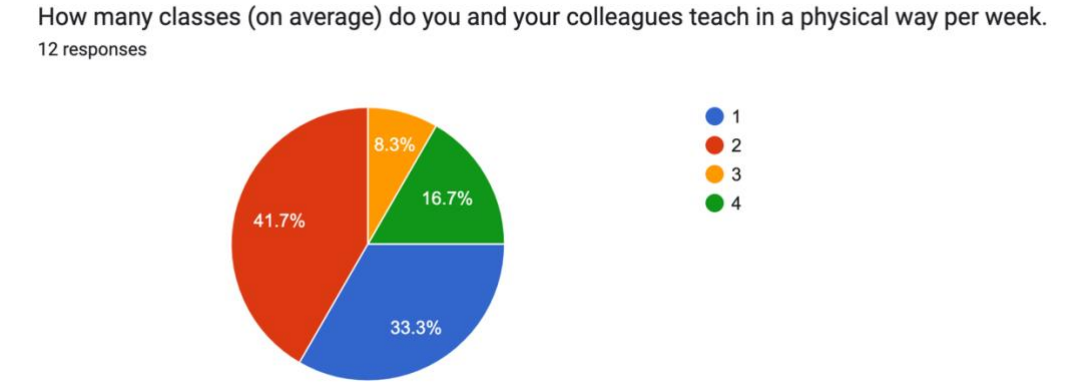

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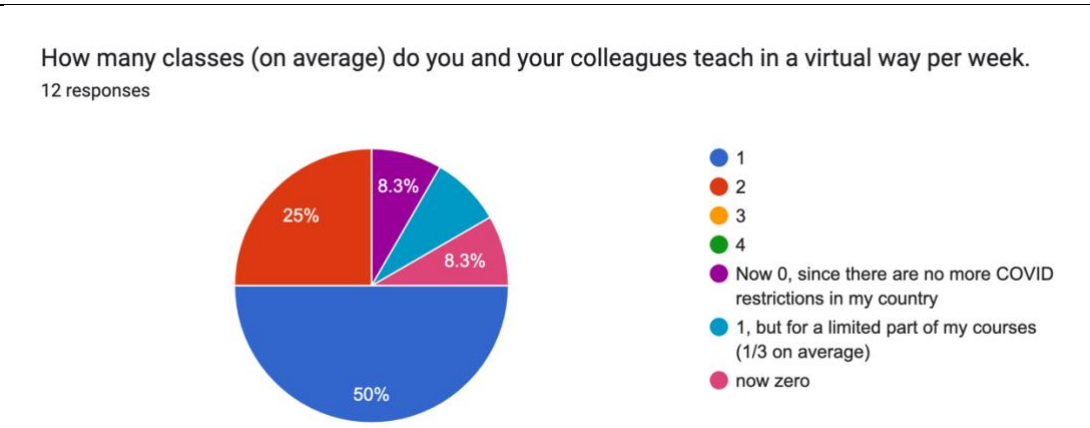

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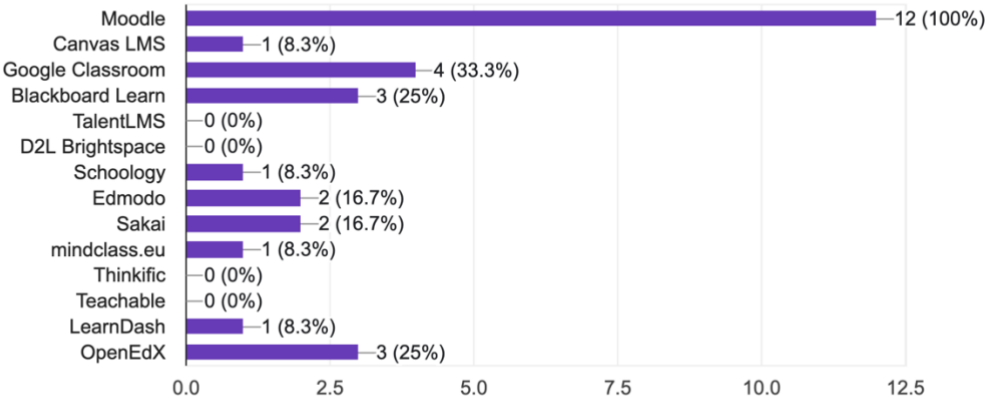
20.

What technologies do you know to be used for student class management? (click all that apply)

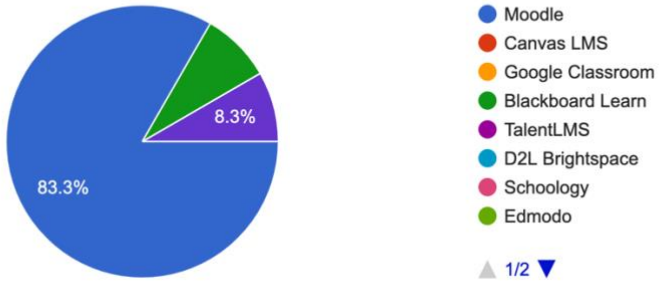
12 responses



21.

What technologies do your institution use for student class management? (select all that apply)

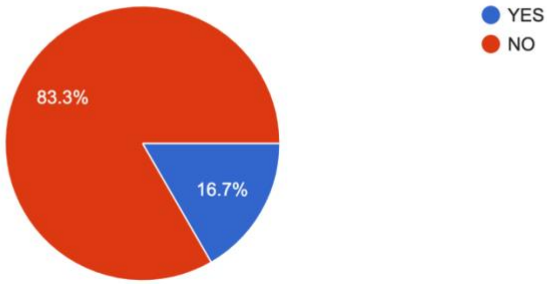
12 responses



22.

Have you heard about EduGain before?

12 responses



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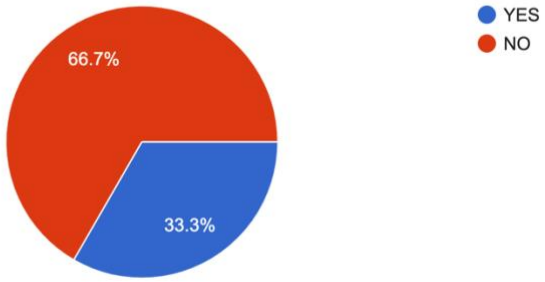
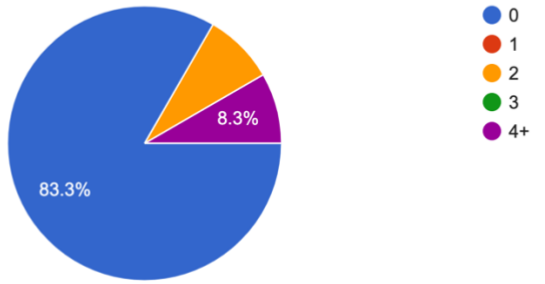
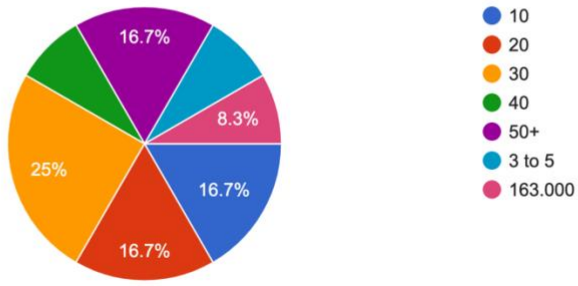
23.	Do you know about the Jupyter notebook solution for the virtual class laboratory? 12 responses 
24.	How many use-cases implemented in the Jupyter notebook do you know/have? 12 responses 
25.	How many students do you have, in average, in virtual classes? 12 responses 
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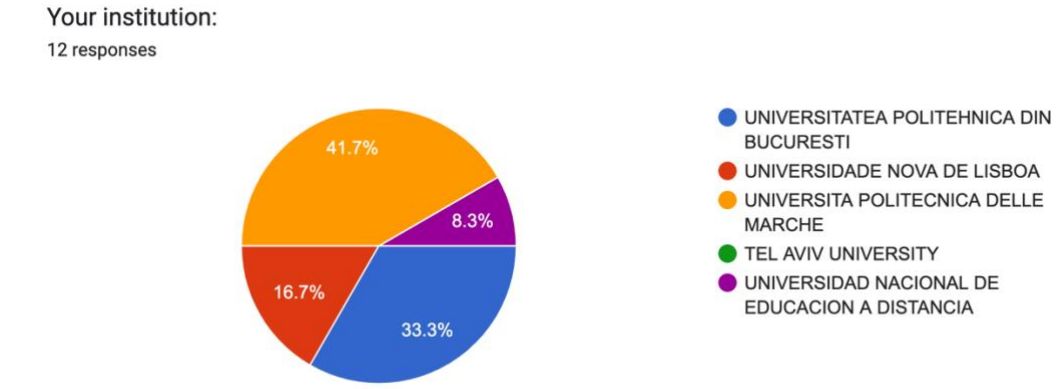
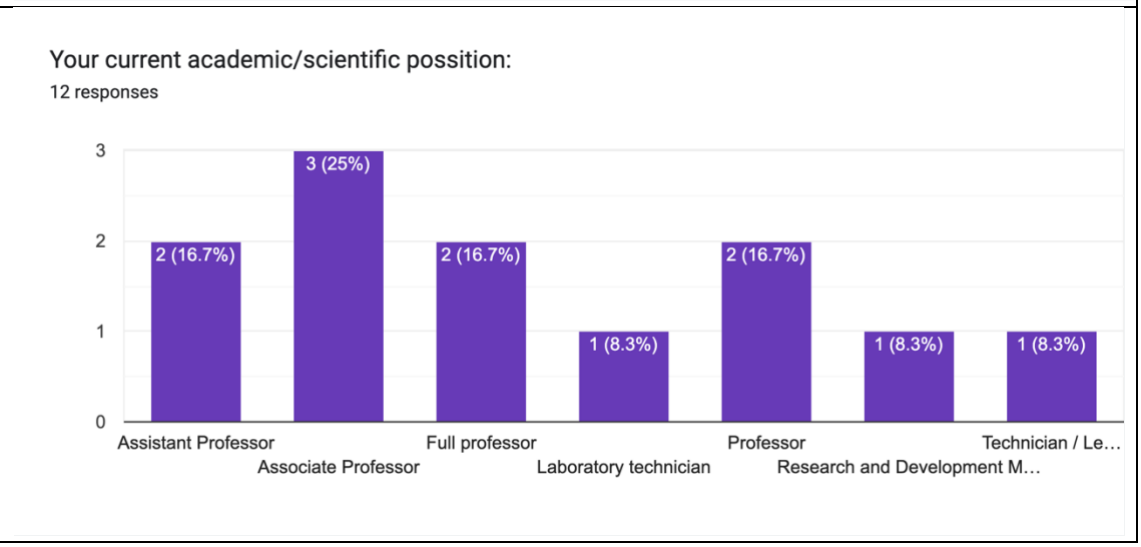
26.	
27.	

3. For the Labs – reproducible Science

By looking at the answers, several aspects can be identified. First, all partners use in a form or another the Moodle open-source platform for LMS. By looking at different other universities in Europe and beyond, Moodle seems to be one of the most preferred LMS platform to support online teaching activities.

However, the problem with Moodle is locality. The platform is usually installed within the premises of a university and integrated with only the Identity Provider service of that institution. An Identity Provider is the service that deals with institutional accounts and credentials (accounts for students, for professors, for administrative personnel, etc.). But such an approach works for people located within the premises of that university – for a remote user it is harder to verify identity online alone, not to mention it is simply not working for partnerships.

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Just to give an example, at the 2017 Gothenburg Summit, European Union (EU) leaders outlined[3] a vision for education and culture. In its December 2017 Conclusions, the European Council called on EU Member States, the Council and the Commission to take forward a number of initiatives, including "*…strengthening strategic partnerships across the EU between higher education institutions and encouraging the emergence by 2024 of some twenty 'European Universities', consisting in bottom-up networks of universities across the EU which will enable students to obtain a degree by combining studies in several EU countries and contribute to the international competitiveness of European universities.* ".

What this means is that Universities need to establish a framework for collaboration. And this is exactly what the project LLSF is encouraging. If one university has established a prestigious class X and another one another prestigious class Y, students should find the means to attend somehow both classes. We'll not discuss the immense complexity in forming joint learning programmes to support such a collaboration, but from a technical perspective with the local Moodle this is simple impossible. It would mean one student should have another account registered with each of the two universities, when being one unique person. And this simply cannot work administratively, because usually the student is enrolled with only one university.

To present our approach, let's look at Figure 1 below.

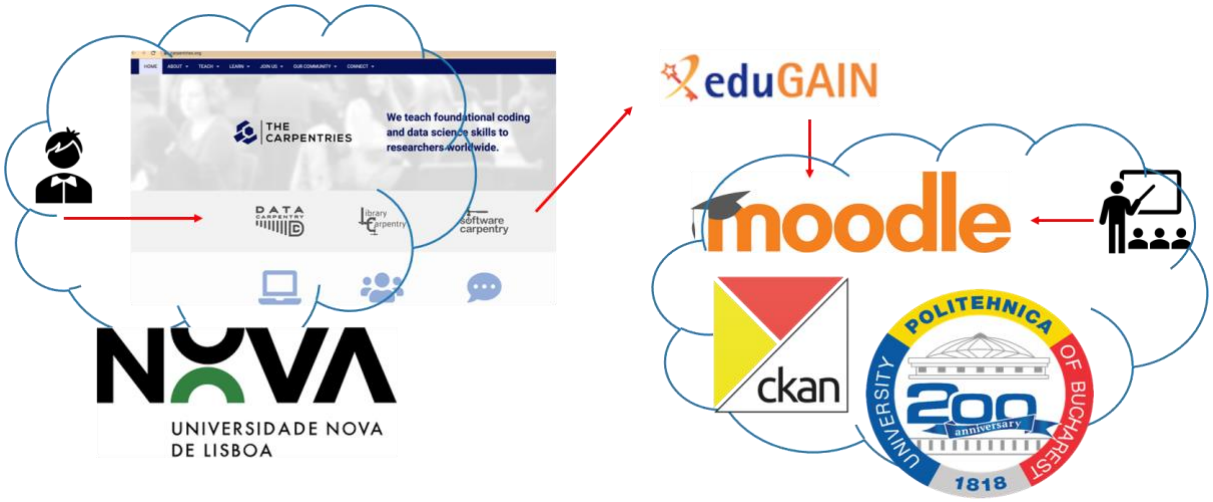

Fig. 1. The LMS collaborative approach in LLSF.

The solution for us consists of an integration with another service, called eduGAIN[4]. The eduGAIN interfederation service connects identity federations around the world, simplifying access to content, services and resources for the global research and education community. As of the writing of this report, eduGAIN comprises over 70 participant federations connecting more than 8,000 Identity and Service Providers.

[3] https://education.ec.europa.eu/education-levels/higher-education/european-universities-initiative
[4] https://edugain.org/

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Today, online services are crucial for research and education. Students, teachers, researchers, and institution staff rely on them for collaboration through many web services. This can be for e-learning, teaching, and conferencing, analysing and sharing data, accessing journals and libraries etc. With just **one trusted identity** provided by user's institution as part of an identity federation participating in eduGAIN, users can access services from other participating federations.

In other words, we see one Moodle instance being installed with each university, as it is now the situation (as seen in our responses from questionnaire). Each university has an internal IdP (Identity Provider), that would be registered in the eduGAIN federation. And then each Moodle instance is registered as an *education service* in eduGAIN.

Now what will happen is that, as seen in Figure 1, a student from Universidade Nova de Lisboa, Portugal, using the credentials already provided by the university, would access remote the Moodle instance provided by the University Politehnica of Bucharest in Romania. And this instance in Romania would correctly recognize the credentials and, even better, would have access to the associated identity (user is a student or is a professor, the function for example according to the Lisboa IdP). From this point on, if a class is configured to allow access from any student from Universidade Nova de Lisboa (or to particular students or cohorts) the access to the online class content is made available.

Of course, students would not know of all possible classes all around the world they have access to. But the solution is quite simple, and we take inspiration from the Carpentries[5] project – simply build a catalogue of classes linked to the remote location of resources for each joint programme offered to students.

Now, the resources being placed in the Moodle instance is not enough. In LLSF we discuss about developing Digital Labs and properly adapting the teaching methods to online characteristics. One idea is that students should have access in their classes, as much as possible, to Data. For example, in the Big Data class being taught at the University POLITEHNICA of Bucharest (UPB) students are presented with challenges based on sets of data: *please present your conclusions from an analysis of the data pertaining to this particular phenomenon*, for example. To present students with such challenges encourages them to critically think their solutions. They need to show how they reach a particular conclusion, what are the rationales behind their steps in the analysis, to be able to motivate their work methodology in particular (so the result is not alone important, but rather how they get to their results is praised).

For this particular purpose, universities should be able to give access also to *data*. If a student from Universidade Nova de Lisboa enrols in the Big Data class at UPB, she will need access to the datasets to complete the learning challenge. With eduGAIN, this is not a problem. Each university has an institutional data repository, usually based on technologies like CKAN[6], Dataverse[7], Invenio[8] or others. If this is not the case, the data could also be stored with a generic data repository, such as Zenodo[9]. Based on the answers from our questionnaire such data repositories exist or will soon be deployed

[5] https://carpentries.org/become-instructor/
[6] https://ckan.org/
[7] https://dataverse.org/
[8] https://inveniosoftware.org/
[9] https://zenodo.org/

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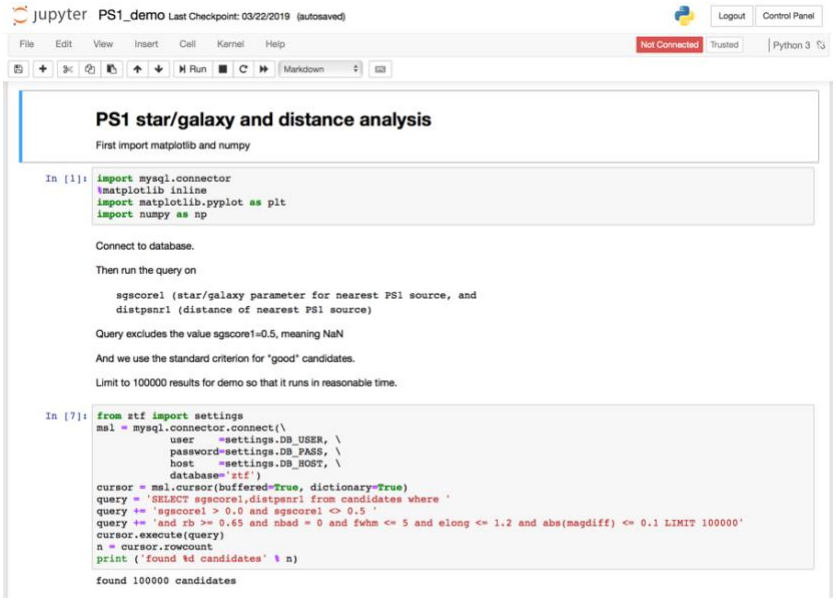
with each university. For us, this is good news, as data repositories could also be registered in eduGAIN as Service Providers. This means, like with Moodle, that a student could be correctly recognized in the data repository at UPB with her credentials from Universidade Nova de Lisboa.

And, of course, the same logic could apply to a bunch of different other digital tools classes rely on. Any digital tool can be registered in eduGAIN as a Service Provider, and then integrate the recognition of remote Identity Providers as part of the credentials correctly accepted for authentication and service provisioning.

One important such tool is Jupyter Notebook[10]. The Jupyter Notebook is an incredibly powerful tool for interactively developing and presenting data science projects. Notebook documents are documents[11], which contain both computer code (e.g., Python) and rich text elements (paragraphs, equations, figures, links, etc.). Notebook documents are both human-readable documents containing the analysis description and the results (figures, tables, etc.) as well as executable documents which can be run to perform data analysis.

The Jupyter Notebook has exploded in popularity since late 2014, fuelled by its adoption as the favourite environment for doing data science. It has also grown as a platform to use in the classroom, to develop teaching materials, to share lessons and tutorials, and to create computational stories. Educators everywhere are adopting Jupyter for teaching.

The Jupyter Notebook App, supporting the execution of Jupyter Notebooks, is a server-client application that allows editing and running notebook documents via a web browser. The Jupyter Notebook App can be executed on a local desktop requiring no internet access or can be installed on a remote server and accessed through the internet. And, more importantly according to our responses in the questionnaire, many universities provide classes based on application on top of Jupyter Notebook App.



[10] https://jupyter.org/
[11] http://ipython.org/notebook.html#notebook-documents

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Fig. 2. An example of a Jupyter Notebook.

On top of Jupyter Notebook, in recent years a plethora of tools were developed. For the use in the class, there are various problems that can appear. For example, if the user presents students with an assignment to be delivered and graded as a Jupyter Notebook, if might happen that it runs on the student's computer but when downloaded it doesn't run on the teacher's computer. Of course, there are different environments, like the Operating System, version of phyton/R or whatever is used for the kernel, different libraries, and so on and so forth. So, the teacher might think to create a common Jupyter Notebook environment on the university servers, where both her and students work collaboratively.

JupyterHub[12] brings exactly this kind of power of notebooks to groups of users. It gives users access to computational environments and resources without burdening the users with installation and maintenance tasks. Users - including students, researchers, and data scientists - can get their work done in their own workspaces on shared resources which can be managed efficiently by system administrators.

JupyterHub runs in the cloud or on your own hardware and makes it possible to serve a pre-configured data science environment to any user in the world. It is customizable and scalable, and is suitable for small and large teams, academic courses, and large-scale infrastructure.

If the university doesn't run a local data center, a remote cloud could also be used. And then, a tool like Binder[13] offers an easy place to share computing environments to everyone. It allows users to specify custom environments and share them with a single link. Use cases involve workshops, scientific workflows and streamline sharing among teams (of students, for example).

The Binder Project builds tools that reward best practices in reproducible data science by utilizing community-developed standards for reproducibility. When repositories follow these best practices and are hosted in an online repository, then Binder automatically builds a linkable environment anybody can access. This includes also linking with Data Repositories like the ones mentioned above.

Binder is today widely used for teaching and training. In fact, Binder allows the sharing of links to interactive data analytics environments with students. This is great for workshops, tutorials, and classes and allows to get students up-and-running with the code much more quickly. For example, Software Carpentry (mentioned before) uses Binder links for their novice Python lesson.

Binder is quite adaptable. It allows for example teacher to share remotely technical documentation. The Binder tools can be used to provide interactivity to documentation and demonstrations of tools. It has been used extensively. For example, the scikit-learn (a collection of classifiers students can use to learn machine learning) documentation[14] uses Binder to let users try their examples.

Binder can provide interactivity to readers, allowing them a richer experience with the content. For example, UC Berkeley uses Binder to let others interact with open data science textbooks. Binder also provides a shared interactive environment along with code and analysis. A person can share a link that

[12] https://jupyter.org/hub
[13] https://mybinder.org/
[14] https://scikit-learn.org/dev/auto_examples/classification/plot_classifier_comparison.html

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lets others reproduce and interact with her work. For example, the Neurolibre project uses Binder to reproduce neuroscience analyses.

So, in our case all these digital tools could be easily part of the educational system, part of activities in classes belonging to the IoT or BigData domains, and even more important, be integrated with eduGAIN to allow for remote access to educational resources to students from all over the world. Completely out-of-the-box, such tools (Jupyter Notebooks, JupyterHub, Binder, Zenodo, etc.) give users access to computational environments and resources without the hassle of installation and maintenance tasks.

Students would simply connect, each to their own copy of the environment, and develop content as directed, often writing short segments of code. Jupyter Notebooks need to become part of the remote Classroom we are developing in the LLSF project (see Figure 3).

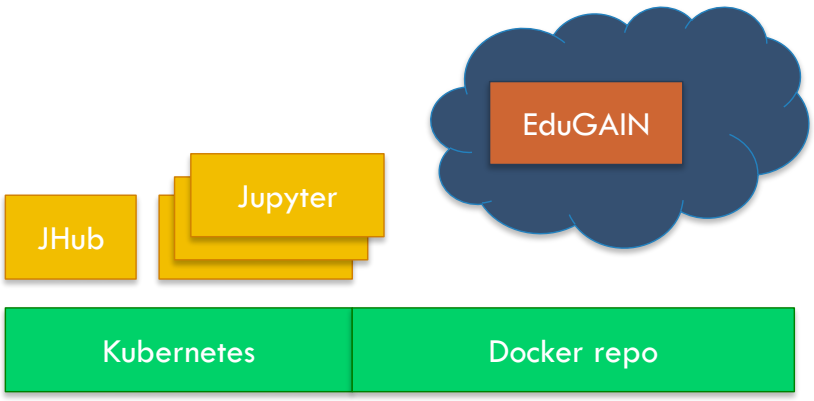

Fig. 3. The landscape of technologies to be used in LLSF.

In Fig. 3, everything runs in the Cloud or on the servers provided by each university. Each university provides a virtual running environment, and Docker is one of the widely used technologies for this. The applications in the infrastructure are to be orchestrated by a technology like Kubernetes (although others, like Docker Swarm, also work). On top, the shared environment is provided by Jupyter Hub and/or Binder. Such environments also connect to the data repository (of the institution or the one in the Cloud, like in case of Zenodo). Students are presented with assignments in order to better understand the theoretical foundations they receive from materials presented in Moodle. The critical thinking process needs to be properly documented, so the teacher decides to force them to work and document their code as Jupyter Notebooks. The code connects to the data over Jupyter Hub, is submitted and graded over similar tools and in the shared environment. And the student can be part of any university taking part in the classes provided by any other joint university, as it is correctly recognised in terms of credentials and identity thanks to the integration over federalisation in eduGAIN.

Such an approach has the potential to be used as a teaching tool for both specific course content and programming languages. It allows for flexibility for instructors and students, or for accessible coding environment. Additionally, it is highly relevant for investigations in applied academic research.

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Of course, the process continues, as presented in Figure 4. Many other digital tools could be integrated in the education process in a similar manner. Like, for example, students could remotely use a simulator for Smart Cities. Or for Smart Agriculture, and so on and so forth...

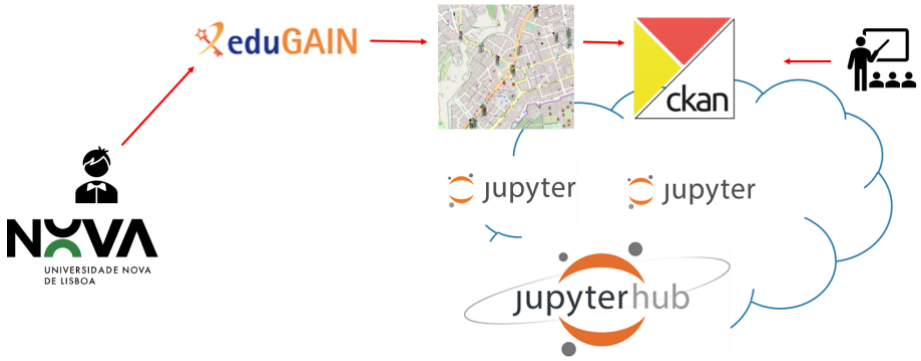

Fig. 4. The potential of the LLSF project.

2. Set of available products and services identified for Smart Labs

2.1. Moodle for class management

Using a Learn Management System (LMS) for class management is a must for any class, being it traditional, mixed, or based exclusively on remote learning. For the management of living labs classes, we chose Moodle as LMS to support the digital interaction between students, instructors, and collaborators.

Moodle[15] is one of the most popular Open-Source Learn Management Systems (LMS). The usage of on-premises hosted Moodle instances is free for anybody, with respect of GNU General Public License (GPL) v3 license.

The core version of Moodle (using no plugins) includes 15 different types of activities (docs.moodle.com, 2022) including *Assignments, Chat, Forum, Lesson, Survey, Wiki,* and *Workshops*.

In addition to being one of the most complete LMS solutions, Moodle stands out compared to other solutions with several attributes that make it suitable for use in the project. As a few examples of them, we can enumerate:

- **Accessibility** - Both versions 3.10 and 3.11 of Moodle are Web Content Accessibility Guidelines (WCAG) 2.11 AA compliant. Certification is planned by version 4.0.
- **Internationalization (I8n)** - Moodle is translated into 100+ languages.
- **Highly customizability** through plugins (including a big library of certified plugins), themes and Learning Tools Interoperability® (LTI®).

[15] https://moodle.org/?lang=ro

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- **Data management** - Moodle includes extensive tools for personal data management, making it easier to complain to GDPR requirements.

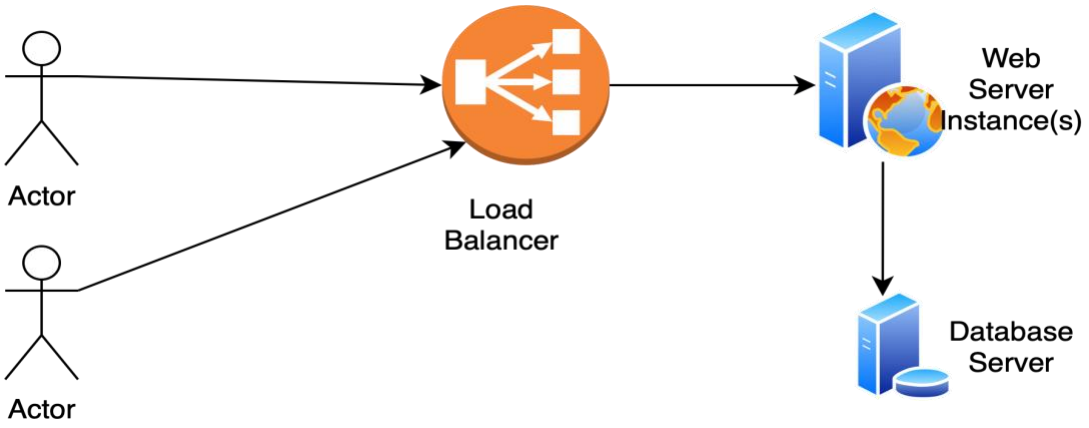

Fig. 5. High level architecture for a modern web application.

Based on our previous experience, Moodle is a very useful tool for both fully remote as well as for mixed teaching classes, ensuring a unified digital reference for class management.

To be used for collaboration, a Moodle instances should be run on a server. The high-level architecture for a typical deployment of a modern web application (as Moodle) is depicted in Fig. 5, which also emphasis the presence of multiple components that should be configured. While bare-metal installation of each component might ask for an extensive system administration experience, there are a few solutions (as Docker) that might simplify this process for us.

In this section we present a step-by-step tutorial for running a Moodle instance on a Linux server using Docker.

To accommodate a production-ready deployment of Moodle, we will create two Docker Swarm stacks named *proxy* and *moodle*. The *proxy stack* will accommodate the Load Balancer, while the *moodle* stack will accommodate the other 2 components of the application. Even for a single machine deployment, the usage of a load balancer recommended for multiple reasons, including the ability of hosting multiple web services on a single server.

In this tutorial, we use nginxproxymanager[16] as a load balancer which will:

- Efficiently handle the HTTP requests from the users.
- Allow us to host multiple web services on a server with a single public IP address.
- Block common exploits.
- Handle SSL secure connections.

[16] https://nginxproxymanager.com

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The *moodle* stack will accommodate the Moodle webserver instances as well as the database server. For easier setup, as web server instance we will engage a Docker image[17] (from Bitnami) which includes the Web Server as well as all the needed PHP configuration and source code.

At the beginning of this tutorial, we assume that you have already installed Docker-CE on a server running Linux. Step-by-step tutorials for the installation of Docker can be found at https://docs.docker.com/get-docker/.

Useful documentation can be found at the following addresses:

- Nginx Proxy Manager: https://nginxproxymanager.com
- Bitnami Docker image for Moodle: https://bitnami.com/stack/moodle/containers

Step 1: Instantiate a Docker Swarm cluster

```
docker swarm init
```

Listing 1. Bash command to initiate Docker Swarm.

Step 2: Create an external network for the communication between the two stacks

```
docker network create --driver overlay --opt encrypted --attachable --scope "swarm" proxy_net
```

Listing 2. Command to create external network named proxy_net.

Step 3: Create the YML docker compose file for the *proxy* stack

The docker compose file we use is inspired by the Quick Setup guide of Nginx Proxy Manager[18] and it should look as the one in Listing 3.

```
version: '3.6'
services:
  app:
    image: 'jc21/nginx-proxy-manager:latest'
    networks:
      - proxy_net
    ports:
      - target: 80
        published: 80
        protocol: tcp
        mode: host
      - target: 443
        published: 443
        protocol: tcp
        mode: host
      - "81:81"
    volumes:
      - data:/data
      - letsencrypt:/etc/letsencrypt
```

[17] https://github.com/bitnami/bitnami-docker-moodle

[18] https://nginxproxymanager.com/guide/#quick-setup

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```
volumes:
  data:
  letsencrypt:

networks:
  proxy_net:
    external: true
```

Listing 3. Docker-compose file for nginx-proxy-manager.

Step 4: Deploy the proxy stack.

```
docker stack deploy -c proxy_stack.yml proxy
```

Listing 4. Docker deploy command.

Deploying the stack described in Listing 3 from a file called “proxy_stack.yml” takes the issue of the command in Listing 4.

Step 5: Deploy Moodle stack.

The Bitnami Docker images automates most of the Moodle installation. To have the stack running, we should deploy the stack in Listing 5 using the command in Listing 6.

```
version: '3'
services:
  mariadb:
    image: docker.io/bitnami/mariadb:10.5
    environment:
      - ALLOW_EMPTY_PASSWORD=yes
      - MARIADB_USER=bn_moodle
      - MARIADB_DATABASE=bitnami_moodle
      - MARIADB_CHARACTER_SET=utf8mb4
      - MARIADB_COLLATE=utf8mb4_unicode_ci
    volumes:
      - 'mariadb_data:/bitnami/mariadb'
    networks:
      - db

  moodle:
    image: docker.io/bitnami/moodle:latest
    networks:
      - db
      - proxy_net
    environment:
      MOODLE_DATABASE_HOST: 'mariadb'
      MOODLE_DATABASE_PORT_NUMBER: '3306'
      MOODLE_DATABASE_USER: 'bn_moodle'
      MOODLE_DATABASE_NAME: 'bitnami_moodle'
      ALLOW_EMPTY_PASSWORD: 'yes'
    volumes:
      - 'moodle_webroot:/bitnami/moodle'
```

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```
    - 'moodle_data:/bitnami/moodledata'

volumes:
  mariadb_data:
    driver: local
  moodle_webroot:
    driver: local
  moodle_data:
    driver: local

networks:
  db:
  proxy_net:
    external: true
```

Listing 5. Docker-compose file for the moodle stack.

```
docker stack deploy -c moodle.yml moodle
```

Listing 6. Deploy command for Moodle stack.

Step 6: Configure the Load balancer.

As described in Listing 3, the configuration interface of the load-balancer as a webpage on port 81. The default username and password for the administration interface are

- Email: admin@example.com
- Password: changeme

By default, Moodle webserver runs port 8080. In order to have it exposed through the load balancer, we should configure a reverse host as in Fig. 5.

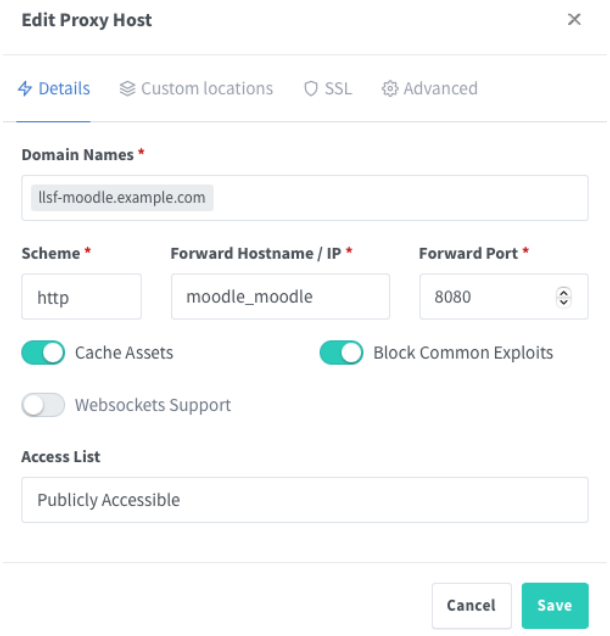

Fig. 6. Reverse proxy configuration.

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For any in-production usage, make sure you also set the parameters in the **SSL** section according to your policy.

Step 7: Access the website

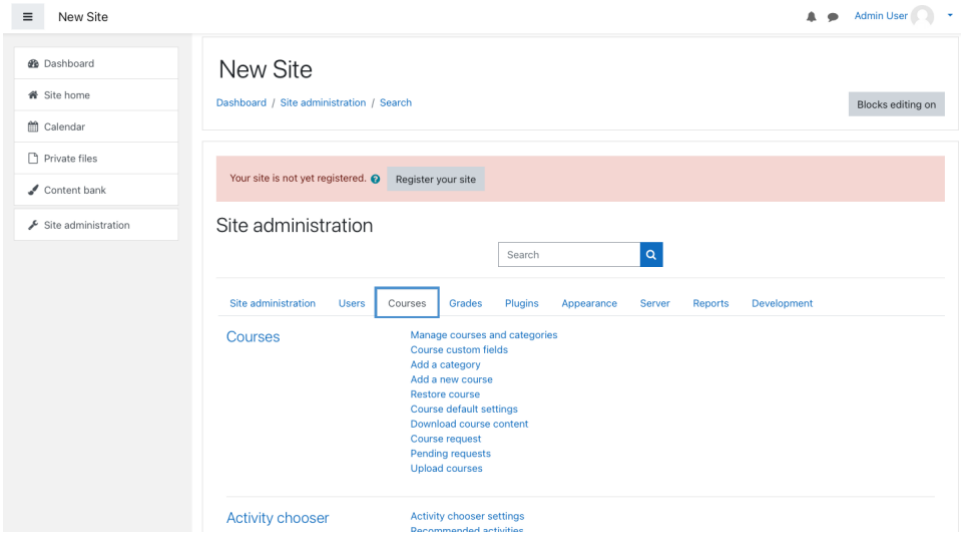

Figure 7. Moodle site administration page.

Once the installation is finished, the Moodle instance will be accessible at the URL of your choice, and you will be able to access the website and start creating courses on your instance.

The default admin username and password are:

- Username: user
- Password: bitnami

Make sure that you change all the default accounts before going public with your Moodle instance.

3. Missing components/elements/services to enable interconnection identified for Smart Labs

3.1. Identity/login management

As a cluster for open ideas, the technical implementation of the tools will come with the challenge of managing the authentication and access control for a big number of actors (students, teachers, researchers, and auxiliary personnel).

While manually granting access for each participant might look like a good solution for a project with a small number of participants, it can easily become an unbearable burden when we talk about 100s or 1000s of participants, with different roles in different institutions.

The eduGAIN interfederation service connects identity federations around the world, simplifying access to content, services and resources for the global research and education community. eduGAIN

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connects more than 8,000 Identity and Service Providers and helps nearly 27.000.000 students, researchers and educators' access online services while minimizing the number of accounts they must manage. By interconnecting more than 70 federations around the world, eduGAIN enables more than 3500 Service Provider to easily identify their users with minimal costs.

From a functional point of view, EduGAIN acts as an automated aggregator of metadata enabling the interoperability between multiple Research and Education Federations (REFEDS) entities founded mostly by a National Research and Education Networks and the Internet Society.

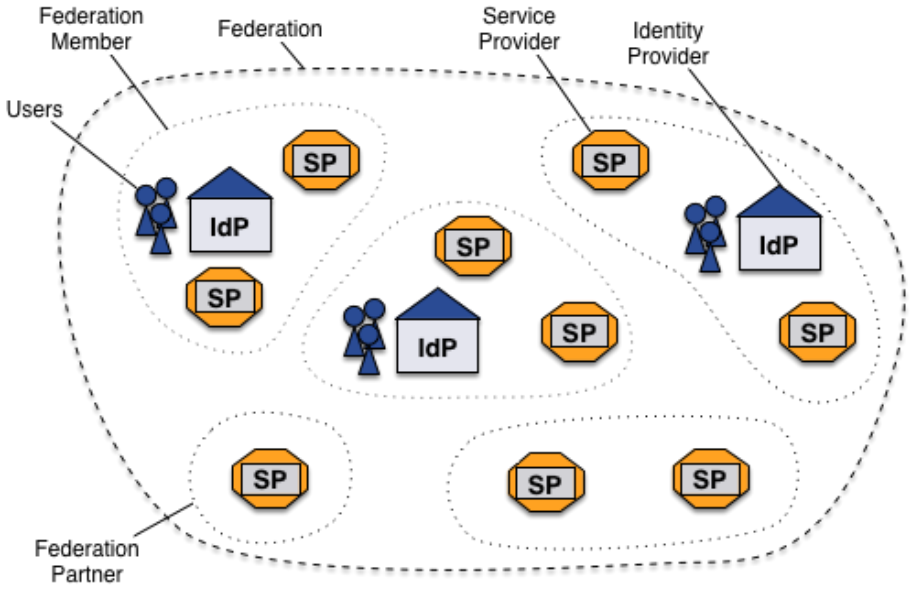

Figure 8. EduGAIN types of components (Source [19])

On the user side, EduGAIN comes as a help for both minimizing the number of accounts each user must manage as well as a technical solution for automatically proving the academic status, using the authentication source from the home organization (e.g., university, research centre, etc.).

To take advantage of the opportunity of using eduGAIN as roaming authentication method, we aim to engage the SSO (Single Sign-On) authentication for most of the services that require academic status validation and/or extended exposure to beneficiary from other academic organizations.

To achieve the goal above:

- Each institution involved should become an IdP (Identity Provider) in EduGAIN.
- Each institution offering a service should become a SP (Service provider) in EduGAIN.

Useful information about joining EduGAIN can be found in public websites such as:

- EduGAIN main website: https://edugain.org
- EduGAIN technical site: https://technical.edugain.org
- EduGAIN section of the GEANT Wiki: https://wiki.geant.org/display/eduGAIN/eduGAIN+Home

[19] *https://wiki.geant.org/display/eduGAIN/Identity+Federations+and+eduGAIN*

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Joining EduGAIN as an IdP involves access to the internal SSO system of educational/research you want included in the inter-federation. Therefor the IdP registration is most likely to be done by the IT team in the institution.

After the SSO gateway is ready, the IdP/SP should be advertised in the EduGAIN inter-federation. Directed by the status of the EduGAIN, research/educational entities should join EduGAIN through the Federation in their country. This is usually administrated by the National Research and Education Network. A list of the current federations in EduGAIN can be found at https://technical.edugain.org/status. Each entity which wishes to join EduGAIN should contact the Federation inside the home country.

In Table 1 we present an extract of information that can be useful for the partners in the project to get in touch with the suitable federations.

Table 1. EduGAIN federations in different countries.

Country	Federation	Federation Page	Contact email
Romania	RoEduNetID	https://eduid.roedu.net/	eduid@roedu.net
Israel	IUCC Identity Federation	https://iif.iucc.ac.il/home/	info@iif.iucc.ac.il
Portugal	RCTSaai	http://rctsfederation.fccn.pt/	noc@fccn.pt
Italy	IDEM	https://www.idem.garr.it/index.php/en	idem-help@garr.it
Spain	SIR	http://www.rediris.es/sir/	sir@rediris.es

A set of Frequently Asked Questions and answers about EduGAIN integration:

Q1: How can I check if my organization is already federated and part of EduGAIN?
A1: Check your email/domain at https://technical.edugain.org/isFederatedCheck/.

Q2: How can I check if my organization is registered as an IdP / SP?
A2: Search the entity using EduGAIN Database Explorer: https://technical.edugain.org/entities.

Q3: How can I test the integration of the IdP in my organization?
A3: One should check the Attribute Release check at https://release-check.edugain.org.

3.2. Jupyter Hub cluster for running remote living labs

Jupyter Notebook is an Open-Source software component that allows to run computational components through a web-based interface (as in Fig. 9).

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```
[1]: from matplotlib import pyplot as plt
     import numpy as np

     # Generate 100 random data points along 3 dimensions
     x, y, scale = np.random.randn(3, 100)
     fig, ax = plt.subplots()

     # Map each onto a scatterplot we'll create with Matplotlib
     ax.scatter(x=x, y=y, c=scale, s=np.abs(scale)*500)
     ax.set(title="Some random data!")
     plt.show()
```

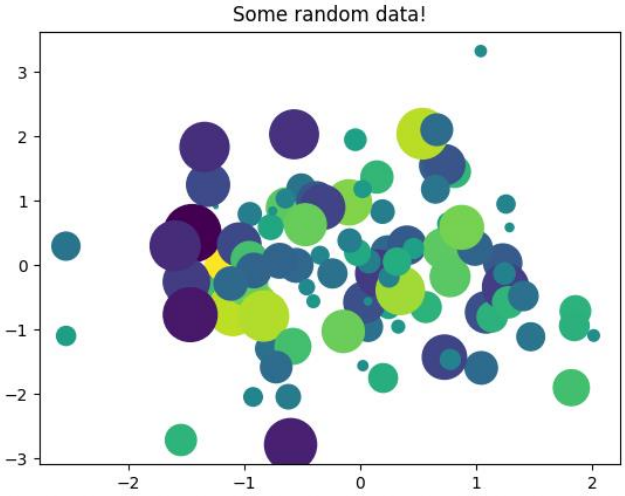

Figure 9. Screenshot in Jupyter Notebook.

This web-based GUI approach is ideal for learning laboratories since it combines the flexibility of writing code in mode than 40 programming languages with the easy visualization of the results. Through a Jupyter Notebook, the students can easily interact with the code given by the instructor as well as developing new snippets of code and experiments.

Containerized **Jupyter Notebooks are also important vector of reproducible research** since they allow the researchers to share their code along with easily accessible methods to visualize the results and create new experiments.

Running Jupyter notebook on Windows/Linux/MacOS

Assuming you have already installed Python 3.x on Windows/Linux/MacOS workstation, running Jupyter Notebook only takes two easy steps:

Step 1: Installing Jupyter Notebook using pip

```
pip install notebook
```

Listing 7. Installation of Jupyter Notebook.

Step 2: Running the notebook

```
jupyter notebook
```

Listing 8. Running Jupyter notebook.

The default and most used programming language for Jupyter Notebook is Python. By default, is uses the global Python environment on the machine it runs as any python script run by the current user.

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Since different laboratories might have different requirements (in terms of installed libraries), it is recommended to run each Jupyter Notebook on its own Python virtual environment as in Listing 9.

```
# Create a new virtual environment
python -m venv venv
# Activate the virtual environment
source venv/bin/activate
# Install Jupyter Notebook
pip install notebook
# Install any other dependencies (requests as an example)
pip install requests
# Run jupyter notebook
jupyter notebook
```

Listing 9. Installing Jupyter Notebook using a virtual environment.

With the setup in Listing 9, resuming the work with a Jupyter notebook only takes the 2 steps in Listing 10.

```
# Reativate the virtual environment
source venv/bin/activate
# Install any other dependencies (requests as an example)
pip install requests
# Run jupyter notebook
jupyter notebook
```

Listing 10. Resuming the work on a Jupyter Notebook installed on a virtual environment.

Running Jupyter notebook using Docker Containers

Even though running Jupyter notebooks on virtual environments can help us running multiple projects asking for different dependencies, installing a large set of dependencies can still be tricky and take a lot of time.

In cases when the initial setup for a Jupyter Notebook is complex, running them using Docker containers can help working around the complexity of the initial setup.

Jupyter Docker Stacks[20] offers a set of easy-to-run prebuild Docker images for different scenarios and setups and base images for creating new setups as well.

The images offered through Jupyter Docker Stack are publicly available on Docker Hub and they can be easily used by anyone. For example, the command in Listing 11 starts a Docker container running the image for the R language on port 8888 of the local machine, using the current folder as working directory.

```
docker run -it --rm -p 8888:8888 -v "${PWD}":/home/jovyan/work jupyter/r-notebook
```

Listing 11. Running R-language notebook using Docker.

Running the command above, the latest jupyter/r-notebook image will be automatically downloaded and the Jupyter notebook container will start shortly.

[20] https://jupyter-docker-stacks.readthedocs.io

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Once the Jupyter server is running, a secret token will appear on the console and the user can access the instance by accessing http://<hostname>:8888/lab?token=<token> on the browser.

Adding new dependencies (libraries) to an existing Jupyter Docker Stack image is also very simple. For example, the Dockerfile in Listing 12 adds the libraries in the requirements.txt file to the jupyter/datascience-notebook image using pip. mamba[21] can also be used as in Listing 13.

```
# Start from a core stack version
FROM jupyter/datascience-notebook
# Install from requirements.txt file
COPY --chown=${NB_UID}:${NB_GID} requirements.txt /tmp/
RUN pip install --quiet --no-cache-dir --requirement /tmp/requirements.txt && \
   fix-permissions "${CONDA_DIR}" && \
   fix-permissions "/home/${NB_USER}"
```

Listing 12. Dockerfile adding requirements to jupyter/datascience-notebook image using pip (source: https://jupyter-docker-stacks.readthedocs.io/en/latest/using/recipes.html)

```
# Start from a core stack version
FROM jupyter/datascience-notebook
# Install from requirements.txt file
COPY --chown=${NB_UID}:${NB_GID} requirements.txt /tmp/
RUN mamba install --yes --file /tmp/requirements.txt && \
   mamba clean --all -f -y && \
   fix-permissions "${CONDA_DIR}" && \
   fix-permissions "/home/${NB_USER}"
```

Listing 13. Dockerfile adding requirements to jupyter/datascience-notebook image using Mamba. (source: https://jupyter-docker-stacks.readthedocs.io/en/latest/using/recipes.html)

Prebuild (custom) images can be prebuilt and uploaded to Docker Hub (or other container repository) and distributed avoid long building times and ensure fast reproducibility of the computational environment.

Extensive tutorials on building Jupyter Docker images can be found at https://jupyter-docker-stacks.readthedocs.io/en/latest/using/recipes.html.

Jupyter Hub

Jupyter Hub is a container-based multi-user version of Jupyter Notebook which can be run on Cloud or on own hardware to offload the burden of running the notebooks from the actual users to system administrators.

Using this approach, the location of the running code changes from the user's workstation to the location of Jupyter Hub deployment (e.g., university cluster) enabling not just the code in environments that can be close to important resources (e.g., databases, data repositories, live deployments of sensors), but also running computationally intensive tasks (by using Cloud/remote computational power) while using any convenient client (e.g., a notebook) to define the notebooks and interact with the results.

[21] https://mamba.readthedocs.io/en/latest/

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Two important ways of deploying Jupyter Hub are available:

- Zero to JupyterHub for Kubernetes (https://z2jh.jupyter.org/) deploys JupyterHub on Kubernetes using a well-maintained Helm Chart. This approach is suitable for scalable deployments, when considering a big number of users.
- The Littlest JupyterHub (https://tljh.jupyter.org/en/latest/) is a simpler distribution aimed for smaller deployments using a single virtual machine.

Since we aim to create Living Labs available for both homed and guest instructors and students, we consider the deployment of JupyterHub deployment(s) to host the living labs with no special requirements/setups for the participants. This approach might also be required for simplified access to remotely hosted resources.

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