R.7.2. Guidelines for the Development of the Training Materials

for the Project Education 4.0: Living Labs for the Students of the Future (LLSF)

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List of participants

Participant No *	Participant organisation name	Acronym	Country
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2	Universidade NOVA de Lisboa	NOVA	PT
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EDUCATION 4.0 LIVING LABS

For the students of the future.

Content

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1 Introduction

Remote/virtual laboratories are educational resources that should be included inside a course design. They must serve to improve the learning outcome of the students. They can be isolated from other educational resources. Design the experiments that students must perform at the laboratory and correlate them with the course objectives.

For an e-learning course to fulfil its purpose of facilitating student learning, it is essential that all elements of the course are carefully planned. Thus, it is essential that all elements of the course are carefully planned to contribute to the to contribute to promoting the development of the intended competences. This is especially relevant if we will want to include significant practical activities based on remote/virtual laboratories. This means that the pre-design stage of the course is an essential and time-consuming phase. Although it requires time and effort, if carried out properly, it will contribute to enriching the educational experience of the students.

2 Educational Design Methodology

Virtual courses or digital courses are a basic element of distance learning, functioning not only as platforms that provide the tools and resources necessary for learning, but also as meeting resources necessary for learning, but also as meeting and interaction places between teaching teams, tutors and students, who dynamize these spaces with their active participation. These spaces are energized by their active participation. Given their importance, the design of virtual courses becomes an essential aspect to ensure the effective development of the educational activity, even more importantly when remote laboratories are involved.

Learning outcomes are a key element in the curricula of the European Higher Education Area. These outcomes set expectations about what each student should know, understand and be able to do at the successful completion of their learning process. The curricular design of learning experiences must ensure coherence between learning outcomes, learning activities and assessment tests. To this end, it is essential that the teaching applied methods, training activities, the related contents and the assessment system should be geared towards achieving the intended learning outcomes, aligning what we want students to know, understand and be able to do with the way we teach and assess.

This design approach, focusing on learning outcomes rather than content, should be applied not only to the design of full courses, but also to the design of e-learning activities contained within them. When planning the teaching and learning activities to be carried out in the context of distance education, as well as the resources and tools to be provided to learners in this space, it is advisable to adopt a **reverse design** approach. Reverse design is a pedagogical approach that allows teachers to plan their teaching or, in this case, to design the experimental activities of their courses around the learning that students are expected to achieve.

This approach involves identifying the learning outcomes and based on these, determining the assessment evidence that will provide information on the extent to which the learning outcomes have been achieved, the content that supports them, the teaching and learning activities and the resources used. In this way, all elements are aligned with the learning outcomes and effectively support students in achieving them.

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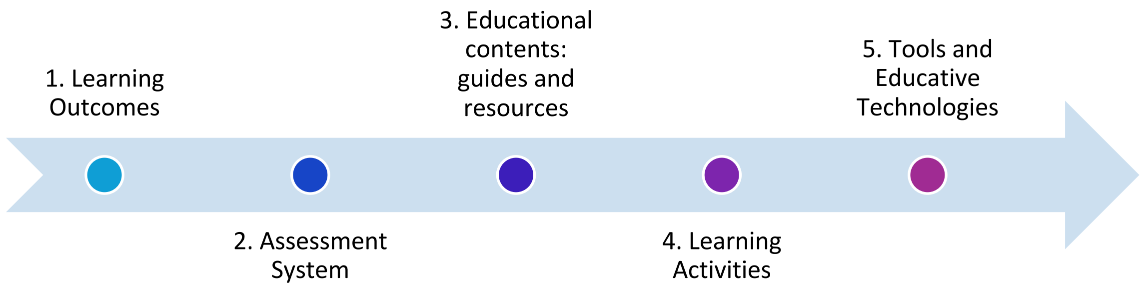

Figure 1. Phases of reverse design methodology

Reverse design can be useful when planning the elements of practical experiments in a learning course. The assessment tests, teaching materials, learning activities and resources to be incorporated in the virtual space should be selected based on the learning outcomes that students are expected to achieve by studying the course. Reverse design, therefore, ensures that the different elements of the learning experience led to the acquisition of the intended learning outcomes. From a learner-centered approach, it ensures that all educational activities are aligned with these outcomes, which increases the likelihood that all students will be able to achieve them.

In accordance with the above, when it comes to designing or updating the virtual course of the subject, the teaching team should consider the following questions:

1. **Learning outcomes**: *What are the learning outcomes of the course as stated in the degree programme or the full course design report?*
2. **Assessment system**:
    a. *What assessment tests will we carry out through the learning experience?*
    b. *Which ones will be part of the continuous assessment process of the learning experience?*
    c. *How feedback will be provided to students on the results achieved and when?*
3. **Educational contents:**
    a. *How will students be able to access the educational contents in which the educational experience is based on?*
    b. *Will we make the teaching material available to students in the virtual course or will we refer them to a bibliography that is not available in open access?*
    c. *What complementary resources and teaching materials will we provide to help them achieve the expected learning outcomes?*
    d. *Who will oversee selecting, developing or adapting these complementary resources and materials?*
4. **Learning activities**:
    a. *What tasks will we propose?*
    b. *How will we facilitate understanding and interaction with the content?*
    c. *In what format (synchronous or asynchronous) will these activities be carried out?*
5. **Tools and Educative Technologies**:
    a. *What tools can we use to promote participation and interaction?*

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   b. *What tools/laboratories can facilitate the achievement of the intended learning outcomes?*
   c. *Are there any tools/laboratories already available for the previous question or is it necessary build them?*

Answering these questions will make it easier for the decisions taken in the design of the learning experience to be based on careful reflection on what the learners' needs are in order to achieve and demonstrate the intended learning.

3 Introduction to the Learning Experience

When students access the learning experience for the first time they will want to know:

- What will I learn by studying the learning experience?
- How will I learn? What learning activities will I have to carry out?
- What will be the basic materials and resources I will need during the study?
- How will I be assessed?

Thus, it is therefore essential that an introduction and an initial studying guide provides all the information necessary to answer these four key questions. This information is necessary to enable learners to self-regulate their learning process effectively, orienting their actions towards the achievement of the intended learning outcomes.

The initial study guide allows students to establish a first contact with the learning experience or course and its teaching staff. For this reason, its design must be carefully considered as it not only lays the foundations for future interaction in the virtual platform, but also influences expectations regarding the course. Although different formats can be chosen, it is recommended that the presentation message of the course be in audiovisual format to make it more dynamic and attractive.

This guide should clearly and directly transmit to the students the basic information they will need to be able to successfully tackle the study of the learning context. It is therefore important that the following aspects are included:

- Presentation of the teaching team and contextualisation of the learning experience in the general framework of the course/degree/university, making reference to the department (or departments) in charge of teaching the subject, as well as the faculty or school to which it belongs.
- Presentation of the learning experience itself, seeking to answer the four questions posed above:
  - *What will you learn by studying this learning experience?* Synthesis of the expected learning outcomes, linking these outcomes to their future professional practice. This connection will allow students to appreciate the relevance and usefulness of the subject, acting as a motivational element for learning.
  - *How are you going to learn?* Description of the methodology to be used in the teaching and learning activities to be carried out. It is important to inform about those synchronous activities planned in the context of the learning experience that students are expected to attend.

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- *What teaching materials should you use?* Presentation of the teaching materials and resources necessary for the study of the learning experience, highlighting those that will be available in the virtual course.
- *What will the learning assessment system be like?* The characteristics of the assessment tasks influence the approach and learning strategies adopted by students. As in face-to-face teaching, one of the first questions teachers have to answer is: what do I have to do to pass the course? or what will the exam be like? Students accessing the virtual course for the first time will be interested in knowing how their learning will be assessed.
- *Communication channels* foreseen for contacting the members of the teaching staff of the subject and, if applicable, the tutor.

A clear and simple initial guide will help students to familiarize themselves with the subject, reduce uncertainty about the tasks to be undertaken and lay the foundation for effective communication between teaching staff and students.

4 Assessment System

The assessment system must be composed of the following items:

- *Guide to the continuous assessment tests and the assessment system of the full course*. It may be useful to prepare a document that includes all the information related to the continuous assessment items and the assessment system of the course. This guide will include the aspects outlined in the following items, '*Detailed description of the continuous assessment tests*' and '*Assessment criteria and indicators*'. In addition, a version of this guide can be prepared for the tutor teaching staff, which includes all the necessary information to guide students in the continuous assessment tests and for the correction of these tests.
- *Detailed description of the assessment items (tests or tasks).* This information will be aimed at presenting the assessment items and contextualising them within the assessment system of the learning experience and its corresponding course. It should enable students to answer the following questions:
  - How does it relate to the learning outcomes and/or content?
  - What aspects is it intended to develop or improve?
  - How many continuous assessment tests should I take?
  - What does each of them consist of?
  - On what dates should I carry them out?
  - What is the weight of continuous assessment within the evaluation system of the course?
- *Assessment criteria and indicators*. The criteria and indicators to be used for the correction of the continuous assessment items will be detailed. At the same time, it is advisable to share with the students the rubric, checklists or other instruments that will be used for the correction, as it will allow the students to know in advance the teacher's expectations regarding the tasks and to understand the reasons why they obtained a certain grade.

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- *Policy against plagiarism*. This policy should be aligned with the normative of the institution and the legal educational context of the course. In addition students should be warned about the use of artificial intelligence in the development of the activities and their related deliverables when it is not allowed.

5 Educational Contents

5.1 Learning Unit Structure

The contents of any learning experience should be organized into blocks of content or more specific teaching units, e.g. modules or themes. A clear and orderly structure of the content helps to reduce the cognitive load, thus aiding the learning process. Organizing content into 'manageable' and logically sequenced units enables students to learn more effectively.

Together with the sequence of content, to promote effective organization of student learning, it is effective to establish a recommended timetable for the realization of practical activities and their study of each of these learning units. Within the flexibility that characterizes distance learning, this timetable will allow students to plan themselves. Additionally, this timetable will allow students to correlate theorical contents with practical activities.

Each learning unit must be composed of the following elements:

- *Unit introduction*. Brief presentation of the contents of the unit and the learning outcomes that students are expected to achieve by studying it. It should also contextualize the unit within the full learning context and establish connections with other units of the programme. This presentation can be done in different formats, such as text, graphics (infographics, concept map, etc.) or audiovisual.
- *Study orientations*. Effective strategies should be proposed to the students in order to successfully tackle the study of the unit. At the same time, emphasis should be placed on those aspects of the content which may be more difficult to understand in order to facilitate their study.
- *Mandatory contents*. It is important to detail the specific parts of the basic bibliography in which the contents corresponding to each unit are addressed and the different ways of accessing it. In turn, if the resources are available in digital format and open to the educational community, the link to it can be provided. In the following subsection, some tips for the development of this type of content will be offered.
- *Complementary resources*. In addition to the basic materials, it is recommended that teaching teams provide other materials that help students to achieve the intended learning outcomes. In turn, it is important that students are informed about the availability of these resources so that they can access them. These complementary materials may include resources developed by the teaching staff (e.g. video lectures, summaries, concept maps, etc.), but also other available resources selected or adapted by the teaching staff that can be used to complement the material in the learning experience (articles, videos, etc.).
- *Related learning activities*. This item will be fully described in the following section.

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5.2 Creation of educational materials

The development, selection or adaptation of educational materials should be carefully planned and justified, based on their contribution to the expected learning outcomes. It is not advisable to enrich the e-learning course without a clear educational purpose, as this could unnecessarily increase the cognitive load of the learners and undermine the purpose of these resources. This does not exclude the possibility of including complementary materials aimed at extending knowledge beyond the learning objectives, always indicating this circumstance.

Educational materials should be adapted to the characteristics of the target audience and the level of difficulty of the subject. Teachers shall ensure that these educational resources are relevant and appropriate for their students.

When creating digital documents, it is necessary to ensure that they are accessible to people with disabilities and other groups with special needs. To do so, it is suggested to take into account the 10 tips to improve the accessibility of digital documents published in the 'Accessibility Guidelines' derived from the ACCESSIBILITECH Project (2022). In turn, in the case of documents in PDF format, the accessibility checking tool offered by Adobe Acrobat can be used to ensure compliance with this requirement.

Gender-neutral language should be used to promote equity and equal treatment from a gender perspective. To this end, the various guides published by the equality offices of the different universities can be consulted.

And we must always respect the licenses for the use of any material we are going to use.

Efforts will be made to provide educational materials in a variety of formats to suit the different learning styles of students. This will make the content more accessible, responding to the individual needs of each student. Multimedia materials enrich the educational experience and promote learning. Their incorporation in the virtual course increases the motivation and interest of students and, consequently, promotes learning. At the same time, introducing innovative and motivating elements in the virtual classroom, such as animations or storytelling (presentation of content through stories), can make the content more attractive and stimulating for students.

When including videos as supplementary material, it is important for teachers to ensure that the content will attract students' attention within the first minute. Failure to engage students' interest quickly will greatly increase the likelihood that they will stop watching. If it fails to engage students' interest quickly, the likelihood that they will stop viewing it is greatly increased. Thus, the following advices can be applied to the educative video creation:

- A traditional lecture approach is not effective in the virtual classroom.
- Videos included in the virtual course should be short and focus on key concepts. Therefore, a maximum duration of 5 minutes is recommended.
- Learning through multimedia resources improves when we exclude elements that, although interesting, are irrelevant. Consequently, when designing a video, one should avoid including elements unrelated to the content (for example, background images, music, symbols, etc.), which can divert the student's attention from the main message.
- Multimedia presentations that use a conversational style, rather than a more formal one, are more effective.

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- There is no solid evidence to justify that incorporating the teacher's image throughout the presentation benefits learning. However, videos that alternate the teacher's presence with slides are more attractive than those that only show slides.
- Students tend to show greater interest in those videos in which the teacher speaks more quickly and with enthusiasm.
- Incorporating active learning strategies into videos can significantly contribute to the understanding and consolidation of learning content. An effective strategy for this purpose is to include short interactive self-assessments immediately after the videos. These self-assessments will allow students to self-check the acquired learning and consolidate it through the test effect.
- It is advisable that videos are subtitled or that the student is offered the possibility of activating the subtitles. In addition, to facilitate accessibility for students with visual impairments, it is recommended to include video transcripts in text format or provide audio descriptions.

6 Learning Activities

The learning activities proposed by teachers to facilitate the acquisition and consolidation of the contents corresponding to each unit must be carefully designed. It is essential that these activities are closely related to the expected learning outcomes and aligned with the contents of the related learning unit. In this way, they will fulfil their purpose of contributing to the students' achievement of the intended learning outcomes.

Learning activities can be carried out online (e.g. answering a quiz available in the e-learning course or participating in a discussion forum) or outside the context of the e-learning course (simulators or virtual laboratories). In turn, they can be designed with different degrees of synchrony (synchronous or asynchronous activities), which will influence the level of interaction between the teacher and the students.

Although the proposed learning experiences will be conditioned by the characteristics of the course and the expected learning outcomes, when designing or redesigning these activities, it is advisable to consider the possibilities offered by the learning technologies such as remote/virtual laboratories. And we should also bear in mind that we can combine our experimental activities with other activity tools on educational platforms such as:

- *Self-assessment activities based on self-correcting quizzes*. These questionnaires admit questions with different types of answers. In addition, most e-learning platforms allow immediate feedback to be given to learners after answering the question, so that they can adapt their answer according to the result obtained, or, in a delayed way, after the end of the test.
- *Self-assessment activities based on checklists or rubrics.* Through the 'Workshop' type tools, the teacher can configure the activities so that students can self-assess their work based on the rubrics, checklists or correction indications provided by the teaching teams.
- *Peer assessment tasks*. Online learning platforms, such as Moodle, allow the design of activities in which students themselves evaluate the work of their peers, providing feedback on the process followed or on the result. This methodology not only favours

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active student participation, but also has an important formative value. By assessing the work of their peers, students can reflect on their own performance, improving their learning.

- *Debate and reflection activities through the forums*. This variety of forums is a very useful tool for developing activities that promote the exchange of opinions, discussion of specific content and even reflection and the proposal of ideas.
- *Collaborative learning activities*, for example, through the Wiki tool that allows students to create and edit a web page collaboratively (although each student can also be allowed to have their own individual Wiki) and to carry out simple monitoring through the 'History' and 'Comments' tabs.

These tasks can be easy integrated into the experimental activities with remote/virtual laboratories to improve the learning outcomes of the students and its participation into the learning experiences.

In addition, the experimental activities must always be accompanied by complementary multi-format material, prepared or selected by the teaching team, to guide the development of the activities. It is also usually advisable to have videos for learning associated with experimentation, presenting both the fundamental concepts involved in the activity and a guide to the tasks required.

With regard to these activities, it is important for teaching staff to bear in mind that students can be reluctant to use third-party tools or platforms that involve the processing of personal data. Therefore, any activity proposed by the teaching staff that should take into account the use of tools provided by the university.

7 Tools and Educative Technologies

7.1 Comunication

Spaces for communication between the teaching staff, tutor teachers and students contribute to improving the educational experience, especially in distance learning. Therefore, we must consider what strategies we are going to carry out throughout the course to interact effectively with students. When establishing these strategies, the following basic principles of academic and digital communication should be kept in mind:

- *Social and teaching presence*. Social presence refers to the perception of connectedness among all participants, while teaching presence refers to how the teacher is perceived within the virtual course. Both aspects are essential for students to feel that they are part of a learning community.
- *Synchronous and asynchronous communication processes*. Synchronous communication facilitates immediate interaction, fostering motivation and reducing the feeling of isolation, asynchronous communication allows for more reflection and task orientation. Therefore, integrating synchronous (e.g. videoconferencing or real-time chat) and asynchronous (e.g. discussion forums, e-mail, etc.) forms of communication can provide a more complete and effective learning experience.

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- *Dialogue and active participation.* It is essential to offer experiences that allow students to take an active role in the interaction processes, both with teachers and with their classmates. Through reflection questions in the forums or collaborative problem solving we can encourage this active participation.
- *Media integration and convergence*. The combination of traditional and new digital media, and their convergence on a single platform, allows the educational process to be adapted to the individual needs of students, fostering more dynamic and participatory learning and promoting a culture of collaboration and knowledge sharing.

Taking into account the previously justified principles, the learning experience must provide several communication channels based on tools such as forums, chats, webconference tools and news feeds to provide agile and easy-to-access communication channels between students and lecturers.

7.2 Laboratories characteristics

A problem with remote laboratories is associated with the specific definition of the term itself. In the literature we can find many inconsistent and confusing definitions, and often, different terms are used to define the same concept, ie, e-labs, web-labs, virtual labs, online labs, learning distributed laboratories, …

To avoid ambiguity, we will first identify three criteria that allow us to classify laboratories based on the type of experiment to be performed:

- Depending on the level of user interactivity with the experiment. Within this category we find two types of laboratories.
  - The user directly controls the devices and instrumentation equipment, which corresponds to a traditional laboratory.
  - The use controls devices and instrumentation equipment through a computer interface using virtual instrumentation or virtual reality environments.
- Depending on the nature of the type of experiment. We can find two sets of experiments:
  - Those performed with physical equipment.
  - Those performed with models simulated / emulated for real devices.
- According to user and laboratory experimentation locations. Experiments for Internet-based laboratory are available in three forms:
  1. ***Virtual laboratories,*** which support simulation of remote experiments and thus provide added value to education, providing an environment for experimentation without the security issues related to real equipment. Laboratory developers can allow global access to these laboratories by web, or create more interactive versions based on a web server (which accommodates the simulated device or the whole system) managed by the instructor and remote stations for students that allow both online and offline use. Although often they are not considered as effective as practical experimentation, an obvious advantage of these laboratories could be the greatest flexibility offered to students. They allow students to experience various conditions without fear of harm to themselves or the equipment. Similarly, a student can repeatedly performs the same experiment or store the process of implementation, facilitating learning from mistakes or for further analysis. The

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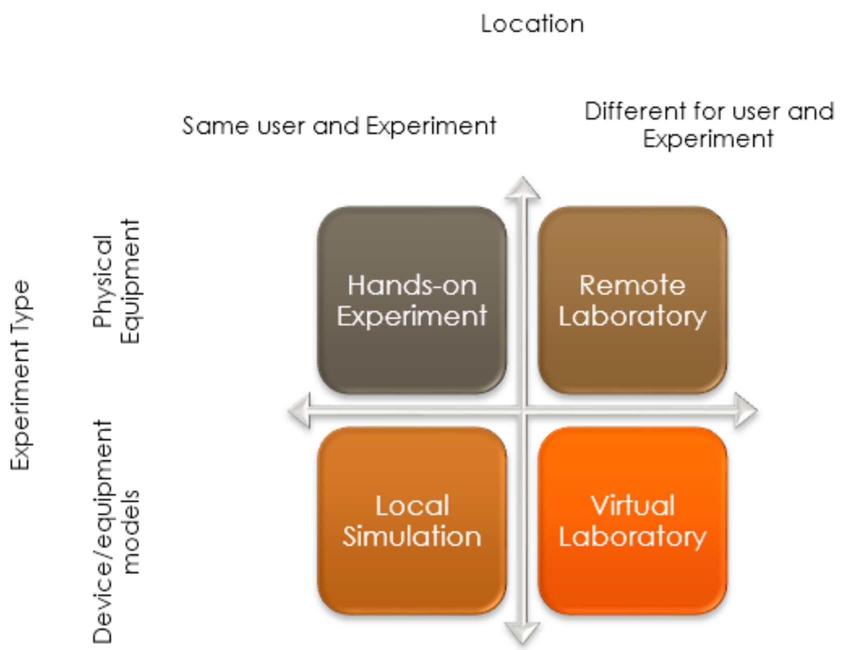
functionality of the virtual laboratory is often reinforced by online courses and step by step instructions that usually accompany laboratory practices.

2. ***"Hands-on" remote laboratories*** or briefly, remote labs, provide users Internet-based access to physical equipments in order to perform experiments. In addition to these individual laboratory activities, there are also inter-university exchange of resources and examples of collaboration.
3. ***Hybrid laboratories*** offer a combination of both previous categories, remote laboratories "hands-on" and virtual laboratories. Among the different types of remote experimentation offered, laboratories hybrids can be considered as the most efficient for education and research. While any practical limitations associated with the use of simulators by physical experimentation sets is solved, the problems of remote security access to physical laboratories also can be addressed by allowing the user initially perform the experiments in a virtual version of the lab, so this way some practice is provided for the use of the actual computer. Even if the emphasis of this work is based on physical devices in experiments, it is important to mention that, in many cases, the distinction between physical apparatus remote control and a web-based simulator is not too obvious to the remote user through Internet connection. Taking advantage of this fact, some complex remote laboratories allow an operating mode where you can have a connection which controls a physical environment to an environment that resembles a concrete simulation environment.



Within the remote experiments, in turn, we can classify them into three groups based on the type of experiments being carried out:

- ***Batch experiments***, in which the student interacts with the remote experiment indirectly by configuring a set of control parameters of the system, and then he/she must wait for the

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outcome of the experiment that will be available from the remote site. So there is no direct interaction between the user and the experiment during its execution.

- ***Interactive experiments***, on the other hand, allow direct communication between the client and the server during the execution of laboratory experiments.
- Finally, ***experiments with sensor platforms***, individual or deployed by sensor networks, which are based on returned data from the sensors to remote users for monitoring and / or analysis purposes.

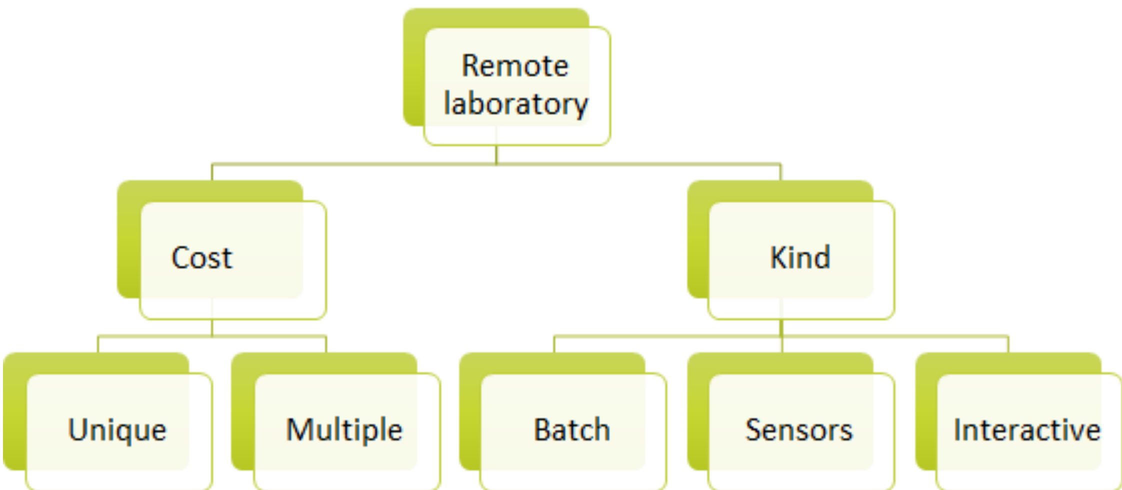
According on these criteria the first questions we must answer ourselves when designing a remote laboratory are:

- What experiment do you want to performs?
- What are the best types of experiments (batch, interactive or sensors) to consider?
- Taking into account the type of experiment; What lab solution is best fit our needs: hybrid, remote, simulated …

7.2.1 Laboratory components

A key feature that determines the technologies that can be used to implement a remote laboratory is associated with the type of experiment, which can be divided into two groups:

- Remote Laboratory experiments associated with an expensive configuration. Often, they are a kind of experiment **"one-of-a-kind"** (common in process control).
- Remote laboratories associated with low-cost experiments that can be replicated without serious consequences in terms of costs (common in digital systems and basic electronic experimentation).



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In the first group, it is common to have one user at a time and the need for a backup system that allows reserving blocks of time to access the experiment. Multimedia services implemented by the remote laboratory server should support the mentoring and providing guidance during the experiment, in order to enable their autonomous use over an extended period of time.
In the second group, the problem of scalability becomes of great importance, and the use of groups of similar experiments can be a solution to support the use of a broad set of users during the same period. In this situation, the selection of specific web 2.0 technologies allow easy replication and integration of additional experiments. It is also possible to take advantage of the redundancy experiment to improve the quality of service, allowing simultaneous use by multiple users at once.
The most common topology for remote laboratories is based on client / server applications and web technologies often exploit, because the client is often a simple web browser.
To implement this topology, we can go to two types of technological solutions:

- Web Based Applications. These web-based technology solutions can benefit from universal and non-intrusive in the sense that they use resources in the client side or use a lesser extent.
- Computer software dedicated to the remote control. These applications have the advantage of supporting more powerful interfaces, taking advantage of the characteristics of the equipment used in the remote laboratory, and its full integration into the desktop environment (allowing specific capabilities, such as complex graphics and data recording). Unfortunately, this solution lacks flexibility and universality.

From this point of view, client technology can be classified into two groups:

- The *intrusive applications*, which should have the same access privileges as the local user of the machine; This is the case of desktop applications (dedicated) and other web-based applications.
- The *non-intrusive applications,* where they concentrate on ensuring that it is not possible any damage to any local resources and where two subgroups can be identified:
  - those dependent on specific plug-ins (such as Adobe Flash)
  - those who do not rely on any plug-in (like for "regular" HTML and Asynchronous JavaScript and XML).

Overall, the intrusive applications provide a better user interface, but can present a deficit in terms of security (if local resources client computers and users are used parts would have to download from the server so it is necessary to ensure that this communication is completely safe, and is not always the case when web technologies are used).
Even in this heterogeneous situation is possible to identify a set of common components in any remote laboratory:

- The ***experiment itself***: a microscope, a telescope, a magnetic levitation system, engine, ...
- The devices and equipment, called ***actuators***, that allow control of the experiment and the acquisition instrumentation of the experimental results, called ***sensors***. This equipment could be based on standard equipment or use custom-designed interfaces.

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- A ***lab server*** to ensure the control and monitoring of the experiment, through control instrumentation devices and equipment.
- A ***server*** that ensures the link between remote users and the laboratory server, typically over the Internet. The solution for this server varies widely, from dedicated applications deployed on web servers (usually presenting a simple description of the experiment and containing additional learning materials) to the delegation to an LMS more complex control operations users and allocation of time for the use of experiments. In that sense, this component can be decomposed into a set of webs (or layers) servers with specific functions: the presentation of related materials (information experiment, theoretical background, and so on), user authentication, book experiment timeslot, management of the learning process, and so on. Not surprisingly, the functions referred to can be accessed through a web portal, as a major customer for experiments or by an institution established by an interagency consortium, providing access to a set of remote experiments.
- ***Server-based video*** and audio that can be used by the remote user to get a visual and audio information of the state of the experiment; this functionality could also be included in the aforementioned web server, but it is common to rely on a dedicated hardware external to the software platform to achieve this goal.
- ***Collaboration tools*** allow audio communications, video and chat among users.
- ***Clients workstations*** ensure remote users connect to the experiment and their associated resources. Importantly, some remote laboratories are based on a simple web browser, while others have to have specific plugins or download client programs in order to get proper access to the experiment (this is the case when using LabView-based platforms servers).

It is important to note that a student does not need all of the above components to establish a remote laboratory with a strong impact on the learning process. However, it is also necessary to emphasize that when a lecturer wants to switch from a remote laboratory based on a single experiment to a remote laboratory provides several experiments to a large number of users, several complex issues need to be addressed, from the stage development and integration of many different topics, such as how to handle the problems of security, scalability, multiple access and other accessibility issues, maintenance, etc..

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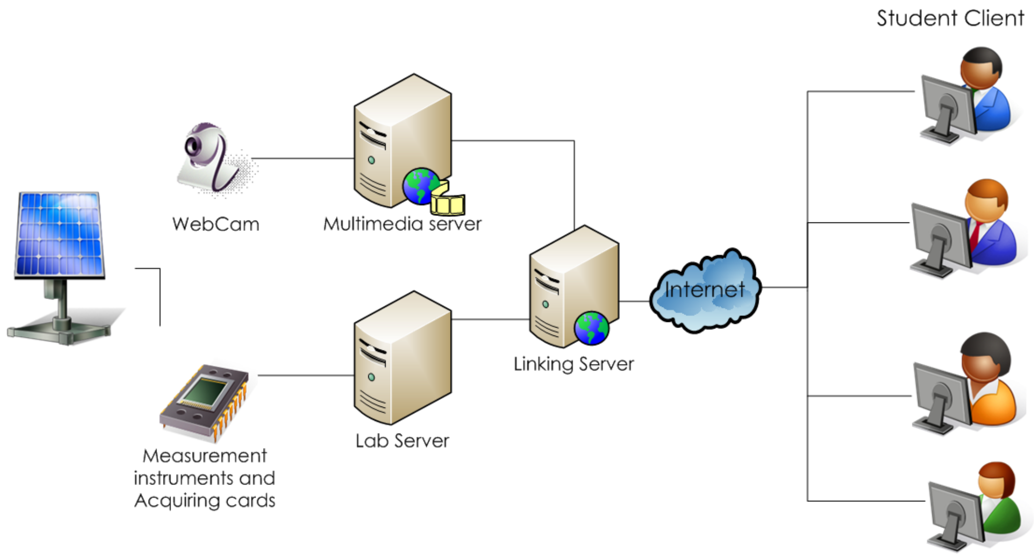

Finally, we pay attention to the communication mechanisms among different parts. If we start from the experiment itself, the communication between the server and the computer laboratory instrumentation can vary, including standard communication interfaces such as TCP-IP, RS-232, IEEE-488, among others, as well as other cases where create ad hoc connections and OEM interfaces. Within this part, if you look at the software used in the connection between the experiment and the lab server, we can find several types of solutions:

- based on proprietary solutions, most of them emphasizing the graphical representation, as in LabView, VEE, and MATLAB / Simulink;
- based on general purpose programming languages, such as C, C + +, Basic, or Python.

7.2.2 Laboratories as a Service (LaaS)

Our approach to the development of laboratories is based on the paradigm of Laboratories as a Service (LaaS). The creation of Laboratories as a Service (LaaS), a service-based utility that allows the use of remote laboratories to be consumed from third parties in a versatile and customizable manner. These LaaS are based on the deconstruction of remote laboratories into smaller “chunks”, which can be combined to allow the creation of customizable remote laboratory experiments. Thanks to this, users of remote laboratories (e.g. faculty) can create experiments that fit their needs and avoid unnecessary functionalities that may jeopardize the acquisition of knowledge by students. This way, the same laboratory can be adapted to the needs of its users, increasing the usefulness of the system – and perhaps also its revenue.

Those services can be implemented following different technologies such as SOAP services, RESTful services or websockets.

The main advantages provide by this approach are:

- Combination of different elements from several laboratories to result in a single experiment.
- Greater adaptability of the experiments to the needs of students.
- Reuse of existing services.
- Uniform access to laboratories.

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According to this paradigm, the basic services that an organization must implement to create a laboratory are:

- Management of the experiment: start and end of the experiment correlated with a session identifier.
- Reading the measurements of the sensors deployed in the laboratory.
- Transferring the corresponding parameters to actuators lab to change the status of the team.
- Indicate the status of the laboratory:
    - Whether or not an error.
    - If a user in the laboratory or.

Additional services that must take into account are:

- Accessibility of laboratories for people with special needs. The graphical client of the laboratory should seek to facilitate its use by as many people as possible: allow resizing to adapt to different screens and zoom to read the text easily, provide alternatives in the graphical elements when possible, as well as offering colour combinations that guide the experiment, use icons that are easy to read, and use the same colour combinations as those used in the experiment.
- Is it a public lab where anyone can connect or is it private and some authentication and authorization mechanism must be set up?. There are several approaches to control user access such as username/password mechanisms, token-based authentication or delegating the log in to the learning platform. Standards such as LTI allow for delegated authentication of users of the learning platform in the laboratory and facilitate logging of activity.
- Depending on the level of lab attendance, there may be a situation where only one student can access the lab at a time. Or we could have a maximum number of students working in the lab at any one time. This is why we should create calendar-based or queue-based access control and booking management services.
- Record laboratory activity during student sessions and other events to facilitate analysis of the laboratory's academic performance and productivity. There are standards such as X-API that facilitate the recording of activity and have application profiles tailored to remote laboratories.
- Sharing laboratories with third party institutions through the federation of laboratories. There is a large field of research in this area and various proposals for standardizing laboratories to facilitate sharing.

7.2.3 Integration of labs into learning platforms

Once we have designed a laboratory and basic services we have to worry about their integration into the educational process. Educational learning environments allow us to combine different services and learning tools to shape the learning process. They are ideal for remote laboratories to be included as a resource context. In the literature we find different approaches to integrate remote laboratories in different VLEs:

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- Remote Learning Management Systems (RMLS) that offer additional services to remote laboratories and also, in some cases, facilitate their integration into online learning platforms. The following table describes the main RMLS found in the literature and their characteristics:

	Labshare	iLab	WebLab-Deusto	Related
Developed by	UTS (Sidney, Australia) [20]	MIT (Boston, USA) [18]	Deusto University (Spain) [19]	UNED (Spain) [21]
Platform	Cross-platform	Windows server	Cross-platform	Cross-platform
Authentication	Username and password and interface to federate australian universities	Username and password	Username and password, LDAP, OpenID, Oauth 2.0	Username and password, OAuth, OpenID
Authorization	Yes	Yes	Yes	Yes
Booking system	Scheduling and queue	Scheduling and queue	Queue	Scheduling and queue
Federation of laboratories	Yes	Yes	Yes	No
User monitor	Yes	Yes	Yes	Yes
Types of experiments supported	Batch and interactive (controlled and uncontrolled)	Batch and interactive	Batch and interactive (controlled and uncontrolled)	Batch and Interactive
Integration of a remote laboratory	Complex	Easy	Easy	Easy
Other characteristics			Mobile access and integration in Moodle	Mobile access and Augmented Reality

More info about this comparative: M. Tawfik, E. Sancristobal, S. Martin, G. Diaz, J. Peire, and M. Castro, “Expanding the boundaries of the classroom: Implementation of remote laboratories for industrial electronics disciplines,” Industrial Electronics Magazine, IEEE, vol. 7, no. 1, pp. 41–49, March 2013.

- Ad-hoc solutions where additional educational tools are added directly to the laboratory.
- Direct integration into the VLE by creating plugins / adapters or exploiting the standards supported by the VLE. In this case we can mentioned several initiatives that focused their efforts on this direction:
  - In the following work “Tobarra, Llanos & Ros, Salvador & Pastor Vargas, Rafael & Hernandez, Rigoberto & Castro, Manuel & Al-Zoubi, Abdallah & Al-Dmour, Mamoun & Robles-Gómez, Antonio & Caminero, Agustín & Cano, Jesus. (2016). Laboratories as a service integrated into learning management systems. 103-108. 10.1109/REV.2016.7444447.” a Moodle plugin is presented for the integration of LaaS.
  - EJSApp. https://moodle.org/plugins/browse.php?list=set&id=27. It is based on Easy Java Simulation and Java Applets. And it is composed by several plugins: activities related to virtual and remote laboratories, management of sessions and management of experiment files.

  As we can see Moodle has been the target LMS for the research community. But the use of laboratories should also take into account in other LRM platforms.
- Use of standards of general purpose for the integration of general applications such as LTI or specific for remote laboratories such as the following options:
  - Project OCELOT. http://ocelot.telecom-st-etienne.fr/index.htm. It is intended to create collaborative experiments. It is mainly developed with java, offers a middleware for the integration to VLE. It is based on IMS content packages. Thus, it is a case of use of LTI standard.
  - Project LILA. http://www.lila-project.org/.. This initiative proposes the integration of the remote laboratories into SCORM packages

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It is clear that there is a need of the definition of common standards in order to share remote laboratories. There are several initiatives in this sense:

- Lab2go. http://www.lab2go.net/
- GOLC Global Online Laboratory Consortium. http://online-lab.org/
- Go-Lab Project. http://www.go-lab-project.eu/
- IEEE Std 1876 – Networked Smart Learning Objects for Online Laboratories: https://sagroups.ieee.org/edusc/

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