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Abstract: In the field of science, technology, engineering, and mathematics (STEM) the use of laboratories to support teaching is a common requirement, not just a possibility. With the rise of the internet, teaching laboratories have changed from 'traditional' hands-on equipment to configurations that allow remote use of the experiment materials. In recent years, online labs (e.g., laboratories of universities or research institutes) have gradually been integrated into 'networks' of labs, with the objective of making them more economically viable, otherwise they would have been short-lived due to the high cost for their development and maintenance. While research on online labs has focused on didactic and technical aspects, there seem to be no in-depth studies on the financial sustainability of technical solutions developed. Moreover, online solutions subvert the traditional pattern of access being limited to individuals engaged in the practice of organizations. Indeed, online laboratories can also be used by professionals and companies interested in research and development, testing, and training activities. The authors of this article frame the problem from the perspective of the servitization of labs of universities and research institutions, through a new business model of a marketplace capable of coordinating the network of labs. To do this, an analysis of the intention to use an online lab marketplace and the activities made available by the online labs is conducted. The analysis involves entrepreneurs and practitioners of various companies from diverse industries in the northern Italy. The analysis is twofold. Firstly, it proposes a survey of intention to use university labs and LNIs in business environment. Second, it seeks to assess the usefulness of a marketplace service that technically manages the relationship between service provider and buyer beyond the mere educational aspects.

Keywords: online laboratory, lab network initiatives, LNI, business model, financial sustainability

1. Introduction to lab network initiatives (LNI)

Laboratories (labs) play an important role, especially in technical education (Feisel & Rosa, 2005). In general science field, lab-based education allows to pursue different important results (Prabha, 2016):

- Acquiring of hard and soft skills, e.g., manipulation and organization of the environment, and maturation of precision, responsibility, and objectivity.
- Conceptualizing hypotheses, theoretical models, and suitably relating to the nature of scientific problems.
- Acquiring cognitive abilities, e.g., critical thinking, problem solving, application, analysis, synthesis.
- Understanding the nature of science and its relationship to techniques and technologies.

Traditional hands-on labs are associated with high costs in terms of equipment, space, and maintenance staff (Gomes and Bogosyan, 2009). For this reason, remote accessible labs have seen a widespread acceptance among universities in the last two decades (Heradio et al., 2016). The reason lies in their ability to pursue same didactical purposes as hands-on labs (Leão et al., 2011) and, in particular, to share costs among the institutions involved in the creation and use of labs (Heradio et al., 2016). Especially in terms of joint initiatives, making labs that communicate with other labs by creating networks of labs allows reducing costs of implementing and using labs (Esposito *et al.*, 2021). In the rest of this paper, the term Lab Network Initiatives (LNIs) is used to refer to these joint initiatives, following Esposito *et al.* (2021), and labs that are accessible using digital technologies are named digital labs.

The pedagogical effectiveness of digital labs and LNIs in the scientific literature has long been recognized (Corter et al., 2004), but several issues arise from a technical perspective, and all these relate to development and implementation of solutions. First, complex and rigorous frameworks and architectures need to be designed, and consequent high-tech technologies need to be identified and deployed (Potkonjak et al., 2016; Galli et al., 2020). Furthermore, other new issues to arise, such as security and safety standards and guidelines to implement both network requirements and local procedures (Uckelmann et al., 2021). As a result, the research community has risen in two main research fields (Zappatore, Longo and Bochicchio, 2015): (i) the pedagogic scenario, and (ii) the

technology stack to implement. Many studies have been carried out to realize feasible solutions for just one field as well as both concurrently (Esposito et al., 2020). What is missing in the literature, to the best of the authors of this paper's knowledge, are suitable studies analysing the financial feasibility of online labs and LNI, namely studies that analyse weather online labs and LNI can 'survive' once that funding institutions and organizations stop funding the development and maintenance of labs. In order to fill this gap, the present paper proposes a survey of intention to use university labs and LNIs in business environment that wants to reply to the following research question: can be viewed online labs and experiments as services that Universities of LNIs can supply to practitioners and entrepreneurs? Especially, the use of labs within the business environment is analysed from the perspective of the usage of a marketplace as the core element to switch to a new servitized business model fostering the financial sustainability of labs. Business players have been identified since they are supposed to enlarge the users possible to provide with lab content beyond traditional academic users especially towards a servitization approach.

The reminder of the paper is structured as follows. In section 2 an overview of LNIs and their proposed contents is provided. The analysis adheres to the work of Esposito *et al.* (2021), who collected information on forty online labs. It then discusses the 'digitalization' and networking of labs is debated as a servitization problem. In section 3 the survey is formalized, presenting the research questions to which it wants to answer, and the scientific approach carried out. In section 4 results from the survey are presented, and finally in section 5 they are discussed. Finally, in section 6 conclusions are addressed.

2. State-of-the-art of digital labs

Digitalized labs can be classified on the basis of three parameters that configure the lab typology and the experiment possible to perform (Esposito et al., 2021):

- The experiment typology, namely if real hardware is used, or mathematical models simulating real device and properly experiments. The former refers to 'Real' experiment, the latter to 'Virtual' one (Bencomo, 2004).
- The experimenter location namely where is the performer of the experiment with respect to equipment and devices to use. Two configurations are possible, namely 'Local' or 'Remote' experimenter, respectively. (Zutin et al., 2010).
- The access typology to the resources, namely if the experimenters perform the experiment directly accessing the material (i.e., on-site), or they access to material via web. Concerning the latter case, it does not matter where the experimenters are with respect to experiment materials, it only matters if the experimenter perform the experiment via internet.

Sticking to the classification of Esposito et al. (2021), digital labs can be laboratories in which perform both (i) real or (ii) virtual experiments, either (i) on local or (ii) by remote, as long as the experiments is performed via web, and this characterize digital labs as online labs: these are in fact defined by Rivera and Petrie (2016) as labs in which the use of internet to access to the experiment allow to perform either physical or simulated equipment/devices.

2.1 LNIs over time

The following analysis comes from the work of Esposito *et al.* (2021). Authors have carried out an in-depth analysis of online labs inserted in funded research project creating LNIs. The analysis is here stressed about financial sustainability of digital labs, which is the topic of interest of the present paper. For other focuses, reader can refer to the original work. Esposito *et al.* (2021) have adopted the structure of Romagnoli et al. (2020) for organizing information into didactical, organizational, and technical clusters, and they made use of official published documentations as well as of direct contact with lab owners for collecting the suitable material of the lab experience. Firstly, the interest of research community has significantly grown in recent twenty years. Online labs of LNIs are often used to teach subjects of Science, Technology, Mathematics, and especially Engineering (STEM). They are generally implemented by universities, both for didactical and research purposes. Most labs (about 3/4 of the total) were publicly funded, with the remaining percentage split between private funding by (i) non-profit and (ii) commercial organizations, about 2/3 and 1/3 of the remaining labs, respectively. Labs funded by commercial organizations experienced the longest activity period, while the most of publicly funded labs expired as soon as funds halted. Finally, concerning this second category, especially labs not inserted in LNIs verified the shortest duration, and it is possible to state that public projects funding LNIs lasted twice as long as other public projects funding single online labs.

2.2 The servitization problem

The concept of 'Servitization' was introduced for the first time by Vandermerwe and Rada (1988), and nowadays can be interpreted as the idea of broadening companies' portfolio of offering from the traditional product-based portfolio to widened portfolio entailing (i) the product and direct related services (e.g., maintenance), but also (ii) customer care practices, and (iii) knowledge and know how (Kowalkowski et al., 2017). In a nutshell, it can be argued that the servitization lies in the concept of providing 'integrated solutions' more than just separated 'product' or 'direct and indirect services'. This process eventually leads to the need of reformulating companies' missions and business models accordingly (Baines et al., 2017). Two technologies have triggered the need for servitization and related business models, namely the Internet of Things (Suppatvech et al., 2019) and the Big Data (Garetti & Taisch, 2012), and more in general the digitalization of businesses and enterprises (Kohtamäki et

al., 2020). This refers to the use of digital technologies to transform business models and provide new revenues and value-producing opportunities (the reader can refer to definition in Gartner for further details, link in APPENDIX A). Digitalization with respect to servitization has translated into the digital servitization, namely the provision of integrated digital services in both physical and immaterial objects, and thus the supplier' offer can be viewed as a group of functionalities customizable on the need of buyers (Vendrell-Herrero et al., 2017).

Several servitization case studies and use cases have been performed in recent years. However, the goal of this paper is not to review the servitization topic, but to give the reader some insights to the concept. We hence only suggest the cases reported in the Emerald' blog (link in APPENDIX A). Accordingly, it is suggested the main approach of providing assets (e.g., machineries, equipment) and intangible product such as tertiary sector services (both in public and private domain), with related advanced services eventually under new form of revenues.

2.3 Result of the review

Digital online labs have grown the academic interest because of their usefulness in pursuing didactical outcomes and providing students with experimentations and materials otherwise not possible to access. However, the financial sustainability of these labs is still to be proved beyond funding mechanism from institutions (both no-profit and business) that allows universities to develop and implement solutions, namely digital online labs use to halt once that institutions stop funding their activities. On the other hand, the increasing digitalization of companies, and more in general, organization shines some light on the possibility to provide lab users with advanced services beyond the traditional contents they supply. Although the digitalization of Universities and mainly lab usages is a matter of fact and a real requirement more than just an opportunity (Kammerlohr et al., 2021), no studies analyse how the use of labs can be considered under servitization perspectives, and can therefore also be proposed to subjects other than students or academic staff.

3. Scientific approach of the survey

The analysis conducted was in the form of an expert interview for investigating intention of business managers and company staff to use or adopt university labs and related advanced services in their business practices. 'Advanced related services' are here meant as quantitative and qualitative results of the experiment performed. This can be raw data as well as information and knowledge gained from elaboration of experiment data, and additional insights directly provided by the lab owner to customers who have performed the experiment or commissioned it as well.

3.1 The Business Model (BM) framework

Next considerations on BM design are consistent with another work that the authors of the present paper are proposing, and which is being submitted to a scientific journal.

The intention to use university labs for business practices has been analysed referring to a BM framework in which three players operate:

- Buyer. The buyer is who accesses the online contents. Buyers can be institutional (universities, companies, research institutes) or individual (students, professors/lecturers, researchers, business practitioners).
- Supplier. The supplier is who provides the online contents. Suppliers typically are universities or companies that own the hardware and software instrumentations and upload the content.
- Marketplace. The marketplace brings the buyer into communication with the supplier, orchestrating the service framework. A service framework consists of technical, didactic, and organizational components that form an ecosystem around the marketplace, for example, standardized architecture, interfaces to third-party systems such as learning management systems, security and safety mechanisms, data protection and privacy, backup systems, data management, booking and accounting tools, order processing, trust systems, virtualization systems such as virtual and augmented reality (VR/AR), learning analytics, and serious gaming.

The framework, especially concerning the marketplace, is consistent with approach of online (i) businesses and (ii) business models.

3.2 Digitalization perspectives leading to new BMs

The digitalization perspectives for defining new BM to which University can refer when proposing digital online labs, especially in business environment, wanted to answer to three main research questions, namely:

1. Does it exist a real need of buyers for making use of online lab and related service?
2. Are buyers willing to pay for accessing and using online labs, as well as taking advantage from evidence from the experimentations?
3. Should be effective a marketplace that manage the service provisioning between buyers and suppliers?

For facing these questions, four themes of digitalization (ToD) discussing the evolution of BMs have been adapted from the work of Ranta et al. (2021). They are listed in the following:

(1) What digital solutions have been used and what principles they have improved (and how)?

(2) What resource flows have been adopted and what have been the resulting financial value creating benefits?

(3) What opportunities and barriers have emerged when solutions have been implemented?

(4) What success and failures related to BMs and BM innovation have emerged, originating from the application of the solution?

These four themes have been then related to each player of the BMs, namely the buyer, the supplier, and the marketplace by using the BM canvas framework (Osterwalder & Pigneur, 2010). Table 1 reports how each building block of BM canvas has been related to three players with respect to digitalization themes 1-4. Building blocks are: Key Partner (KP), Key Activities (KA), Key Resource (KR), Value Proposition (VP), Cost Structure (CS), Channels (C), Customer Relationship (CR), Revenue Stream (RV).

Table 1: ToD matching BM players in BM canvas

ToD	Buyer	Supplier	Marketplace
(1)	KP, VP	KP, VP	VP, KA, CS, KR
(2)	C, CR	C, CR	RS, C
(3)	VP,C	VP, C	CS, VP, C
(4)	VP	VP	RS, VP, CS

3.3 The survey

The survey has been performed via online Google Form (see Appendix A), since limitations to mobility and social distancing due to the COVID-19 pandemic.

A survey with a questionnaire using both close and open questions has been carried out. Questions are structured, and respondents are asked to express a judgement both quantitatively and qualitatively. Agreement with topics proposed by the questions is expressed in a specific Likert' scale, in which respondents' opinion move from the strong disagreement (value 1) to highest agreement (value 5). Moreover, respondents have been asked to answer qualitatively to the questionnaire and they have been free to discuss topics freely, justifying their answers mandatory, if not directly indicated otherwise.

The questionnaire has been designed so that each digitalization theme is discussed by four questions (multiple relations are possible). It has been divided into four sections. First section is devoted to gathering data relative to respondents' affiliations, and they have been collected for only quantitatively analysis. Section 2 is devoted to discovering whether respondents have been ever used digital online labs or not. On the basis of their answers, two patterns are defined, namely section 3 devoted to questions addressed to respondents who already used digital online labs, and section 4 devoted to questions for inexpert users. In both sections, questions relate to (i) the lab typology used or likely to be used, (ii) the quality of the service provided or expected, (iii) benefits and knowledge acquired or expected to gain, (iv) whether or not there was a marketplace managing the access to the contents or it is supposed to improve the quality of the service, finally (v) how much the use of lab and related services costed (and relative feeling with the expenditure) or it is supposed to fairly cost.

4. Results from the survey

Recipients of the present survey have been business entrepreneurs and practitioners of the northern Italy area, mainly located in the Emilia-Romagna region. An amount of 21 respondents have joined the survey, 16 working in manufacturing enterprise and 5 in tertiary sector of services. The most represented cluster relates to companies manufacturing plants and equipment for different industries, however mainly manufacturing for food and beverage sector.

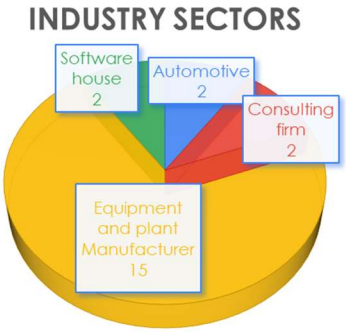

Figure 1: Industry sectors involved in the survey

Out of 21 respondents, 5 are chief officers, 13 are managers of technical divisions, while 3 are simple employees. It has been interesting to discover that all chief officers already had knowledge of digital online labs, and the same applies to only 5 managers out of 10. Although almost the 50% of respondents have knowledge, or information at least, of online digital labs (i.e. 10 respondents), no one has ever used them before, and just one respondents found them not useful to its work, while 62% are interesting in virtual labs and simulations, and 29% in remote labs. One respondent also indicated serious games for acquiring both hard and soft skills.

It is interesting to note that 67% consider digital online labs useful to continuous improvements of (i) business practices or (ii) portfolio of offerings to customer, while 29% are neutral. Moreover, 57% of respondents expect from digital online labs the possibility to perform tests with material otherwise not accessible, and 33% trust in their easiness of use. On the contrary, about the 50% of respondents could be prevented from using online digital labs because of safety and security problems while only 24% judge them still as an immature technology.

Concerning the role of a marketplace as service broker between buyers and suppliers, 57% of respondents are not yet able to figure what values this player can add, and they general figure out a direct access to the platform of lab

owner. However, 48% do not refuse the possibility of having a 3rd party player managing the service framework, and the main reason lies in the trustworthiness of the system (48%), while (i) vouching for transparency of the service and (ii) the provisioning of advanced related services (e.g., storage space for data from the experiments, as well as analytics) equally divide the rest of positive feedbacks (19% apiece).

Finally, concerning the financial sustainability of digital online labs and marketplaces, 67% of respondents have showed a pretty strong belief that they can be viewed as 'servitized offerings' to customer that are supposed to pay for them, and the percentage grows up to 95% if respondents are considered who don't see any particular problem in getting paid for providing this kind of service in business environments. Pay-per-use is the preferred payment typology (67%), while 19% of respondents link the payment typology to the service provided.

5. Discussion of answers

The following comes from open answers given by the respondents.

The main interest of business practitioners and entrepreneurs relate to the ability to run simulations and thus test solutions virtually before to rolling them out in real environments, especially using software, servers, and platforms that would otherwise too expansive to purchase in terms of frequency of use. Moreover, this approach is also intended to trigger scenarios in which personnel who are not skilled in using specific software can directly access the results without having to manage the test themselves. This should reduce both capital expenditures and operational expenditures. An interesting application is the one where the experiment is performed in combinations with the customer, thus jointly defining the design of experiment, and also the multi-criteria decision-making boundaries to control the results obtained. On the contrary, safety and security problems mainly relate to the possibility of stealing data property under non-disclose agreement, but there is still misconception of potentialities of digital labs and possible experiment to perform. This refers to the fact that some people trust there is still no possibility to perform specific experiments, such simulation for optimization of huge equipment plants of food and beverage industry. It could be noted that chief officers, who stated their knowledge of digital online labs, expressed concerns about technical problems, while all other respondents were doubtful because of safety and security issues. Concerning the expected outcomes, the majority of people having a positive perception of the possibilities of digital online labs mentioned the possibility of acquiring further know how and knowledge by leveraging technology transfer with the university through the use of labs and the relative results of experiment, while the negative responses relate to the fact that digital online labs are seen only as equipment that allows practices to be carried out that would otherwise be possible with other technologies.

Concerning the presence of marketplace that allows the connection between business buyers and academic suppliers, the interviewees generally see this actor positively. The acceptance of such a player relates to the transparency of the whole service that a marketplace fosters, but also to the simplicity of finding interesting and useful material in a single place, and also to shorten the time to market of labs uploaded on the internet, and then enlarging the offer, since definition of rules and technical requirements to comply with for joining the marketplace; this is also supposed to make more effective the labs and the network in which they are inserted. On the contrary, such a marketplace is still not understood, meaning that respondents answered that they are not able to figure out how to insert this actor in the network, basically because of it is a 'too high novelty to be worked out'. Moreover, only some answers relate to the fact that a marketplace could enhance the cost for using labs and accessing results. Concerning payment for accessing to and use of digital online labs, it is interesting to note the very business-like approach of these potential users, namely the complete presumption that the 'no pay, no content' rule is also valid for using digital online labs and accessing results and related information. Of course, this is true once that the real usefulness of experimentation set and results achieved is proved, and thus the majority of respondents ask for clearly defining the potentiality of the labs and the perimeter of the experiments. Also, some respondents answered that this approach can help universities in providing better services to students and other entities (researchers as well as industry environments) since it triggers self-funding mechanisms. Finally, pay-per-use subscription is preferred to other since it is supposed to optimize operational expenditures (linked to the lab access frequency). Hybrid approach, in which a basic monthly / yearly subscription is paid, and other services are paid under pay-per-use subscription have been indicated. Moreover, some respondents stated that 'pay-per-use allow better scheduling of experiments'. Conversely, it is interesting that many respondents stated that pay-per-use subscription can be better planned into the corporate budget and managed as an investment.

6. Conclusions

The present paper has been carried out an analysis of intention to use universities' digital online labs and their willingness to pay for accessing the service. The provision of labs over distance can be approached as a servitization problem, since they provide intangible product and related advanced services as (i) lab experimentations and (ii) knowledge from results of performed tests, eventually developing possible new form of revenues, which relates to servitization research field. A BM has been considered in which three players are involve: the buyer of the service, the supplier of the service, and a marketplace that manages the content of networked labs and the business relationship between suppliers and buyers. Then, business organizations of the northern Italy, mainly from the Emilia-Romagna, have been involved in a survey assessing

the intention to use digital online labs and the will of paying for the service.

Results from the survey are generally positive, meaning that there is a pretty strong interest of business environments into digital online labs, and when the usefulness of this kind of service is recognized, then companies are willing to pay for accessing and using labs. The presence of a marketplace is also recognized useful. However, some misunderstandings do exist concerning digital online labs as well as the marketplace's role in the supply chain, or companies are not yet ready to understand the meaning of this actor, at least.

Concerning first point, two examples value more than lots of words. From 'technical' point of view, the lack of interesting labs has been sometimes linked to the unavailability of specific simulations mainly for processing machineries, forgetting that simulations can be 'tailored' on the needs of customers coping with special needs. From BM perspective instead, pay-per-use subscription is sometimes preferred to other subscriptions since it is supposed to allow better scheduling of tests, forgetting that the scheduling needs to be followed by the lab booking, and monthly or yearly subscription would have priority booking, or at least they would provide comprehensive services for which the booking process is more efficient.

Concerning the second point, the presence of a marketplace is somewhere seen as a 'intruder', namely direct access is supposed to make more effective the access to the lab and, to secure the financial relationship among players, while it is well-known that it exactly applies the opposite, namely a marketplace fostering a network of player allow to fasten relationship because of defined solid rules of engagement, also pushing on safety and security aspects, and also it allows to decrease utilization costs by enlarging the offers. This is all the truer with respect to LNIs, for which has been proved that the organization into networks makes more reliable the service, and new way of proposing digital online labs need to be thought for acquiring new funding sources.

However, more in general, large potentialities have been generally recognized to both (i) digital online labs and (ii) the presence of a marketplace regulating the business relationship. For instance, the use of digital online labs for sharing tests on product with customer, and then designing new customized products to sell, sounds as an approach in which the horizontal integration is pursued towards the mass-customization of Industry 4.0. Moreover, it has been largely accepted that the presence of a marketplace can increase the trustworthiness of the whole LNIs supply chain, and also to design a better service.

In a nutshell: although the market is still not fully mature, it is time to move towards new BMs for LNIs, that look to creation of value to business partners by university and research organizations that provide digital online labs.

Finally, future works that are expected to overcome limits of the present paper are discussed. Firstly, the BM canvas has been adopted for identifying area of interest in the digitalization of labs. However, a BM needs to be designed, that consider players and supposed revenue stream for defining new 'rules of engagement' of LNIs with respect to digital servitization. Secondly, the panel is limited in number and respondents all belong to the same geographic area. It should be useful to enlarge the panel, investigating also other areas. Thirdly, no statistics have been performed on quantitative data collected. These could be computed for disclosing interesting insights beyond qualitative discussion, for instance finding patterns that disclose in which field or industry digital online labs are seen interesting technologies, or if there is still a cultural problem to overcome, for instance correlating answers to company positions of respondents. Of course, a larger statistical sample is needed, for not biasing results.

Authors of the present paper are working of some of these topics.

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Appendix A. FIRST APPENDIX

Gartner' definition of digitalization as provided in https://www.gartner.com/en/information-technology/glossary/digitalization. Last access: 2021.03.04

Emerald' blog on servitization at https://www.emeraldgrouppublishing.com/topics/blog/what-servitization-manufacturing-a-quick-introduction. Last access: 2021.03.04.

Questionnaire of the survey accessible via Google Form at link https://docs.google.com/forms/d/1G1i5G-JyiYJuGzbqL-bIkfP2-Oe_5pByM39YdkQxgCI/prefill. The reader is asked to only consult the questionnaire.