Abstract—This article is introducing latest developments and trends in remote and virtual technologies and their application in engineering education. The author gives an overview about the potential of utilizing remote engineering in engineering research, education and professional training, focusing on different kinds of technological characteristics. In conclusion, possible ways of further advancement are presented.

Index Terms—remote engineering, remote lab, virtual lab

I. INTRODUCTION

Nowadays the engineering industry is characterized by rapidly occurring innovations and continuous advancement of existing technologies. Therefore, it is quite a challenge for research institutions to keep up with the high pace of technological advancements in industry by being up to date with facilities, educational concepts and curricula [1,2]. According to Carew and Cooper, engineering is "a field where innovations in technology mean that /.../ connection between engineering curriculum and the technology used in industry need[s] constant attention."[3].

A. Issues in engineering education

Where the utilization of modern technology is finding its way into our digital society, this evolution is accompanied by a lack of adolescent interest in taking part in scientific and technological development, as expressed in [4],[5] and [6]. The engineering qualification has to become more attractive to young people and feasible to full-time employees in order to stay at a high level in product development and to inspire potential engineering students. Engineering research, education and professional training is shaped by the utilization of practical hands-on experimentation facilities (called "labs" from here on), much more than in any other scientific discipline. A particular lab (e.g. an "industrial robot arm" or a "production line") might be too expensive to be purchased by a single research and engineering institution or too large to be placed in a small research facility.

B. Benefits of lab sharing

This raises the idea of sharing labs between different institutions as explained in [7]. Cooper and Ferreira note about remote experimentation, "it appears to offer a simple solution to problems of distance, collaboration, expensive equipment, and limited availability." [8]. Gravier et al. further report other expectations in lab sharing, which are non-monetary and apply quite well for research applications, like "security", "observability", "dangerousness", "accessibility" and "availability" [7]. Taking hazardous research experiments into account, these could be achieved more securely by utilizing remote lab technology. The general idea of equipment sharing without enterprise or institutional borders supports the research scheme of Factors of the Future as it enhances industrial research through mediating access to expensive equipment for technology-driven SMEs or industry. One of such application can be, for instance, a research institution certified tests for industry with remote observation.

In the preface to [9], Zvacek summarizes the advantages of remote labs. According to her, "the benefits are likely to include increased /.../ access to equipment, greater flexibility in lab scheduling, a wider range of possible assignments of activities, and enhanced opportunities for collaboration /.../". The authors' goal in [10] is "to use modern technology to provide students with enough learning opportunities to conduct science experiments that are essential to science education". M. R. Kadhum and S. Kadry notice the "lack of the modern laboratory in scientific institutes"[11] as a reason for the need to develop remote lab infrastructure.

Henke, Ostendorff and Wuttke report about the remote lab's advantages: "it gives the student the possibility to work on real world systems without the need to stand in line at a lab or the need to take care of opening hours"[12]. Facer and Sandford argue that the educational development should "move beyond pedagogy to curriculum; beyond the school to the community, home and workplace"[13].

In a guest editorial [14], Auer and Gravier introduce the many facets of remote labs. Authors in [15-17] discuss the general role of labs in engineering science in more detail.

Summarizing these statements, remote labs offer various advantages over conventional labs, far beyond budget issues for both research and education.

II. LAB SHARING INITIATIVES

There have been several attempts in the last decade to deal with the issues mentioned here. The goals of the iLabs project at Massachusetts Institute of Technology in USA, were to develop a suite of software tools to facilitate online complex laboratory experiments, i.e., "minimize development and management effort for users and providers of remote labs, provide a common set of services and development tools, scale to large numbers of users worldwide, allow multiple universities with diverse network infrastructures to share access" [13], [18-20]. Au-
authors in [21], have compared three web services based architectures of remote laboratories, DIBE ISILab (Internet Shared Instrumentation Laboratory), HPI DCL (Distributed Control Laboratory) and MIT iLab, according to user interactions and interoperability between remote labs. All of these architectures collect in a web service interface all the functionalities exposed by the lab, and use work sessions to structure measurements and store data sent or received from the instruments. The authors also stated that “structuring remote laboratory functions as a set of services has the major advantage of allowing the sharing of the physical experimental setup, while leaving the possibility of customizing the client application interface”.

III. DIFFERENT APPROACHES IN LAB SHARING

Where most approaches [22-26] focus on a single lab integration, the authors in [27-28] suggest a “Service Oriented Laboratory Architecture” approach.

From the interoperability perspective, the authors have tested and proved the possibility of sharing remote experiments between different institutions [29], as did the consortium of the author of this article [30-33].

Currently, there is very little evidence for significant sharing of distance lab hardware between different institutions [34]. Different facilities have their own technological approaches, so sharing is very complicated since external software components and data sources cannot be integrated into existing platforms without major expense.

The requirements in technical knowhow, programming skills and time are too high for most teaching staff. Furthermore, there are no common documentation sets, software platforms or reusable libraries to reduce the workload for a remote and virtual lab provider. The complexity of the common approaches delays the evolution of distance lab solutions and hinders a thematically wider range of potential lab providers and users from participating in distance lab networks.

A. Current limitation in remote lab sharing

To solve the problem of providing practical skills to students despite the lack of equipment and funds in educational institutions, technology enhanced learning based on the sharing of equipment between institutions is suggested for wide-scale implementation across countries [7], [35]. Advances in internet-based technologies allow institutions, SMEs and private individuals to access the equipment of other organizations. However, the main problem today is that there are no standards or recommendations regarding the requirements for such equipment (electrical signals, communicational protocols and compatibility of software). There are merely some suggestions ([35-37]) but no DIN, ISO, or IEEE standards.

Changing the view to subparts and subsystems, there are some existing (semantic) descriptions for various science areas, such as sensor descriptions.

For instance, in 2009 Compton et al. analyzed in [38] 12 different sensor ontologies. While some of them (like Avancha [39] and CESN [40]) are merely descriptions of sensors, other like OntoSensor [41] are also capable of describing ‘components’, or like OOSTethys ‘processes’ in addition. Their conclusion gives the statement that a “combination of OntoSensor and the CSIRO ontology represents the current limit of expressive capability for semantic sensors” [38], but none of them is able to deal with the whole context of sensor descriptions.

For user interfaces it is almost the same situation. Various descriptive approaches exist and are discussed in the Model-Based User Interfaces Incubator Group at W3C. These approaches can be separated into industrial (Collage, Flex, Open Laszlo and XAML for instance) and research driven (CAMELON Reference Framework, MARIA and UsiXML for instance) ones (compare: [42]).

Universities across the world are developing different types of remote labs for their own interests [7],[43-44]. However, there is very little evidence at the present time that such local labs are used by other institutions in order to provide educational support for a wider range of students on a regular basis.

The common web browser is widely used to access remote and virtual laboratories [45-46]. Authors in [47] have introduced the concept of “experiment as a service” and developed a service-based software infrastructure for remote laboratories, called DCL (Distributed Control Lab). Examples of integrated experiments available on DCL are “Higher Stricker” (a real-time control experiment), a programmable logic controller and embedded real-time control applications. This work has been undertaken under the Vet-Trend project [48], with the main objective to build an open infrastructure for conducting robotics and real-time control experiments from the Web. Unfortunately, this concept has not become widespread so far since there is no established standard and the software components used in DCL are not publicly available.

Authors in [49], under a project called VISIR (Virtual Systems in Reality), developed software to allow users in various universities and other organizations to set up online lab workbenches for electrical experiments. The software is used by two universities and students can perform simultaneous experiments on online workbenches.

Several other virtual and remote laboratories have been developed for a variety of disciplines [21],[50-51]. However, the diverse proprietary interfaces, software components and implementations for each experiment are a problem for learners and teachers (no common user interfaces and APIs are used). Therefore, it is hard to integrate new remote labs or create virtual labs. Due to incompatible software implementations it is a hard task to integrate external labs into an existing lab platform. That complicates the sharing of labs between different organizations and universities.

Another major problem that slows down the evolution and distribution of distance labs is that very few qualified staff members are capable of providing lab equipment on the internet, not to mention that it is even more complicated to completely virtualise given hardware components. A strong indicator for this is that most of the distributed labs are engineering related; teachers from other disciplines who lack an affinity to programming are less likely to provide their labs on the internet since they lack the technical knowledge and support to do so. Most of the existing Labs are tailored lab-specific experiments (for instance: [52-55] and use diverse proprietary interfaces and implementations but there is no common user interface and no common APIs, nor a common description of them. Despite that, many labs share similar requirements; new experiments require new developments, logic, connectors and user interfaces. In other words, technologies used in
current labs mainly lack reusability and interoperability, for instance they are not generic enough to be reused when designing and integrating new labs.

IV. CONCLUSION

As a possible solution for the mentioned issues, there is an urgent need for standardization in this field. According to authors in [34], [56-58] a more generalized approach is necessary to establish a wider use of remote labs in research and education. One important step in this direction is the development of a common language for the lab integration [59] as well as a comprehensive soft- and hardware toolbox including documentation for automated plug and play distribution of remote and virtual labs gives an overview of different types of online accessible labs. In addition, there needs to be an adequate implementation of technology-enhanced learning in the practical oriented parts of engineering education by embedding these approaches into learning concepts.

One starting point to conquer these problems is to offer web based technologies for remote access to equipment and eLearning in blended learning education with the assistance of internet-accessible labs and experiments.

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PAPER
CURRENT TRENDS IN REMOTE AND VIRTUAL LAB ENGINEERING. WHERE ARE WE IN 2013?

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