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Engineering Attractiveness in the European Educational Environment: Can Distance Education Approaches Make a Difference?

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Abstract: The recent phenomenon of worldwide declining enrolments in engineering-related degrees has led to the gradual decrease in the number of engineering graduates. This decrease occurs at a time of increasing demand in the labour market for highly qualified engineers, who are necessary for the implementation of fundamental societal functions. This paper initially presents a survey of practices, which are currently employed by academic institutions in Europe in order to increase the attractiveness of their engineering studies. It then provides a detailed analysis of the benefits and proliferation of distance education to increase attractiveness of engineering studies based on a set of interviews. Results of this study, highlight a lack of a distance-learning dimension in the implementation of engineering studies in the European Area and discusses in detail ways in which distance learning can be utilised in engineering studies for the benefit of increasing their attractiveness. It has also been noted that institutions employing distance learning as part of their engineering studies, see this as highly beneficial for their students but also for the academic institution itself with some reservations in terms of the pedagogical adequacy of materials and instructional approaches used in distance education courses.

Keywords: engineering attractiveness; distance education; remote laboratories; virtual reality; augmented reality; mixed reality

1. Introduction

Recent studies [1–6] have revealed a worldwide declining interest in the enrolment of students in educational degrees related to technical disciplines. As a result, many universities have been forced to reduce the number of engineering programmes offered both at the undergraduate and postgraduate level. The declining numbers of engineers is posing a threat towards the healthy growth of the European economy and the speedy exodus from the economic recession. Taking as an example the structure of the UK's economic output [7]: the value added in agriculture accounts for about 1% of the GDP, for industry 21% and for services 79%. Harrison [8] showed that there is good econometric evidence in the UK, that the demand for graduate engineers exceeds supply, and that the economy needs more graduate engineers for both engineering and non-engineering jobs. This is reflected in the sizeable wage premium for people holding engineering degrees, which has been consistently increasing for the last 20 years. Most of the industrialised economies within Europe such as Germany, Italy, France, and UK, are expected to find a long-term sustainable solution to this without any further delay. In the short-term, many employers are recruiting experienced professionals from the international labour market, but in many cases, there are visa restrictions which make the recruitment process very complicated and time consuming. Moreover, although the recruitment of foreign-trained engineers might address the lack of qualified people in the short term, it might aggravate the problem in the long term, turning it into a societal issue. The impact on the economy will be direct, as a large percentage of the local population will be unable to contribute in the industrial sector.

To trace the root of the problem, one must look back into the educational system that is currently followed in Europe and identify possible causes. This paper focuses on examining the extent to which European higher education institutions offering engineering studies effectively utilise their capacity to provide distance-based education, which is one of the main pillars of attractiveness worldwide [9]. Specifically, the paper initially presents an empirical study which aimed to identify current practices employed by universities across Europe in order to increase the attractiveness of their engineering programmes. It then provides a detailed analysis of a number of interviews that were carried out to examine how distance learning practices apply in engineering. The article then discusses how attractiveness could be enhanced through the incorporation of the distance-learning dimension in the implementation of engineering studies, while it presents possible issues associated with it.

The rest of the paper is organised as follows: Section 2 highlights the problem of declining interest in engineering studies and briefly discusses the concept of distance-based education and its potential for increasing the attractiveness of engineering studies. Section 3 presents the survey-based methodology obtained for identifying practices that European universities currently employ in order to increase the attractiveness of their engineering studies. Section 3 also presents the methodology followed to conduct a series of interviews from academics involved in distance education in engineering. Section 4 then gives a brief overview of the survey and interview responses and provides a detailed analysis of the results. Section 5 provides an in-depth discussion on distance-based education's potential use in engineering studies. Furthermore, it outlines the current research projects related to distance education in engineering with emphasis given on remote laboratories. Finally, the paper provides the conclusions of this study and discusses future directions of research.

2. Literature Review

2.1. Declining Interest in Engineering Studies

The number of engineering graduates at the bachelor level in Europe and internationally has been falling, prompting warnings about serious shortage of skilled engineers [1–6]. As a result, societies lack of qualified engineers, especially nowadays when the local industry and economy faces continuous challenges due to globalisation, offshore outsourcing, competitiveness in innovation and technical expertise. To address these challenges, there is an increased demand for more highly qualified engineering graduates. This has led to a series of questions that academia and industry must answer, including the following: What should be done to increase attractiveness of engineering studies, and promote their awareness to potential students of engineering degrees? How can institutions identify the right sort of students for a degree in engineering, ensuring that only those who really want to become engineers are enrolled, and thus decreasing the number of dropout students? As pointed out by Johnson and Jones [3], there are many factors that contributed to this decline—including the difficulty of the curriculum, the attractiveness of alternate paths to good technical jobs, and the lack of attractiveness of projected employment paths for engineering graduates. Furthermore, this could be also attributed to the inappropriate career advising sometimes provided in high schools [9].

Table 1 sums up the main reasons that young students are put off from choosing a career in engineering and science related disciplines.

Table 1. Reasons for not wanting to study Engineering.

	Reason	Description
1	Curriculum is Difficult	Engineering curriculum can be long and difficult, requiring a strong educational background from secondary school years. Engineering curricula typically involve intense courses in mathematics, physics, chemistry etc. [3].
2	Curriculum is Expensive	When compared to other degrees (law, economics, finance, marketing, etc.), engineering degrees are much more expensive.
3	Weekly timetable too busy	Compared to other undergraduate degrees, engineering has a quite busy schedule that makes it demanding and intense. It also makes it difficult for self-funded students to work and study at the same time.
4	The curriculum is densely packed and inflexible	Engineering degrees require a high number of credit hours, thus increasing the cost and making the degree less flexible for students who wish to broaden their experiences through an internship [3].
5	Other paths to good jobs are less demanding	Despite the steady increase in wage premium for people holding engineering degrees, the job market has worsened for young workers in science and engineering fields relative to some other high-level occupations [3].
6	Engineers treated as commodities by employers	Engineers are likely to be laid off when the company is financially underperforming: in some cases, senior engineers are replaced with young graduates with sharper technical skills at a much lower cost, while in other cases their function is offshored.
7	Traditional entry level jobs are being offshored	Many entry-level jobs are outsourced to offshore locations where good technical talent is available at much lower cost. As a result, there are fewer jobs available for bachelor's level engineering graduates, and lower salary offers [3].
8	Impact of Media	Often media provide a negative publicity to the profession through articles on offshoring of technical jobs, and instability in the engineering profession [3].
9	Lack of Diversity in the student population	This applies mostly to women and minority students whose numbers are low because of cultural and stereotype issues [3].
10	Bad career advice	School counsellors in some countries might not have the capacity and the eligibility to give enough details and stir the interest of the students to follow an engineering discipline [9].

Recent results from a study conducted by the Organisation for Economic Co-operation and Development (OECD) indicate that the field of social sciences, business and law attracts most students entering tertiary education [10]. More specifically, on average, almost one-third (32%) of new tertiary students across OECD countries enrol in social sciences programmes, whereas only 15% of new tertiary students enrol in engineering, manufacturing and construction, which is the second most popular field at the bachelor's level. The general outcome of this study shows that the social sciences are the most popular field of study in every OECD country except Finland and Korea, where engineering, manufacturing and construction are top choices, selected by one in four students. The decreasing number of engineers is somehow eased because there are still sufficient rewards in some areas in Europe and US for qualified immigrants to come especially from developing countries [11]. This has become even more obvious during the last few years. The German government, for example, has launched a recruitment campaign to get thousands to come from India to address its shortage of engineers and other scientists [12].

From the literature presented above, it is clear that there is a global anxiety in regards to the shortage of future engineers. The existence of the declining trend has led researchers around the globe to further investigate the matter and suggest potential methodologies, tools and frameworks which can potentially increase the attractiveness of engineering studies, and promote their awareness to potential students of engineering degrees. These suggestions have focused mainly on academic-industry cooperation [5–7], gender and personality issues [8,9,13,14], national-level educational environments [11], and academic-industry cooperation [5]. However, although various aspects of the problem have been addressed, a study on the concept of attractiveness of engineering studies as it relates to distance-based education has not been conducted yet [15].

2.2. Distance Learning in Engineering Education

Distance education is very broad and encompasses several methods of delivery (e.g., regular mail, radio, television, Internet). It is not new, either in general education or in the field of engineering, but has its roots in correspondence courses, which can be traced back to late nineteenth century. The advent of the Internet had a profound impact on distance education, which went through a process of transformation and adaptation to emerge as a new method of e-learning, depending heavily on Information and Communication Technologies (ICT). Distance education now encompasses a variety of technologies, which support both synchronous and asynchronous communication.

Although distance education is a useful framework for engineering studies, it can represent a large variety of pedagogical perspectives. The conventional approach is to provide training and support mainly through a well-designed and predefined course package. The consequence of such an approach is that distance education could potentially be very authoritarian, with pre-packaged course material that could present only a particular perspective. The expansion, however, in the modes of communication enabled by recent advances in ICT technologies, has revolutionised distance education, and is driving the development of learner-led rather than package-led forms of distance education. The appearance of a variety of new tools and technologies fostering computer-supported collaborative learning (CSCL) [15], is leading to the development of new forms of online learning environments, in accord with socio-constructivist views of learning [16]. To understand how these environments operate, one must turn back at the early stages of distance education. Back then, Holmberg used the following definition to describe distance education: " ... the various forms of study at all levels which are not under the continuous, immediate supervision of tutors present with their students in lecture rooms or on the same premises, but which, nevertheless, benefit from the planning, guidance and tuition of a tutorial organisation" [17]. Keegan provided a more detailed definition identifying the main characteristics of distance education [18]. First identifying characteristic of distance education is the physical separation between teachers and learners. Second characteristic is the capacity of the educational institution in delivering such programmes. Institutions offering distance education degrees must carefully attend to programme planning, preparation and delivery of the course content, and provision of support for learners. Third characteristic is the technology and infrastructure involved to enable distance learning by connecting the teacher and the learner. Fourth characteristic is the provision of two-way communication for the students to enable constructive dialogue with their instructor. Finally, the fifth characteristic points out the fact that, due to the absence of a learning group of participants in distance education programmes, learners in such settings are generally taught individually rather than in groups.

In recent years, due to the rapid advances in ICT, we have witnessed a rapid expansion of distance education worldwide as educational institutions at all levels are becoming increasingly involved in distance education initiatives [19]. Online course delivery has become common in a wide variety of disciplines, including engineering. As part of the effort to attract a larger number of competent students in engineering studies and to sustain these numbers, several Universities have resorted to introducing distance education engineering studies mostly at a postgraduate level. In general, distance education is widely used in many countries worldwide. Engineering studies via distance education tend to be offered by a significant number of universities, with their students being remotely located. The expansion of distance education engineering studies is likely to continue in forthcoming years, given the expanding access to the Internet and the greater emphasis given to lifelong learning.

Although the five basic characteristics of distance education outlined by Keegan [18] are widely used/referenced by the distance education research community, they cannot be considered adequate when addressing some of the basic aspects of engineering education in the 21st century. For example, one aspect missing from Keegan's definition [18] is stating the significance for students performing hands-on remote laboratories when adopting the concept of distance education in engineering studies. Also, missing from the definition is the need for close communication and collaboration among learners, which is a vital aspect of engineering education.

Based on Bloom's Taxonomy [20], there are six levels for classifying humans' cognitive process. These are knowledge, comprehension, application, analysis, synthesis and evaluation. Nightingale, Carew and Fung present these six levels from the domain of engineering [21]. More specifically, they first define knowledge as memorisation of facts, definitions, recall of methods and procedures. Second, they define comprehension as the ability to convey knowledge in alternative ways that enable the student to compare, describe explain, discuss or classify. Third, they define application as the step where students apply and transfer knowledge to different contexts and use abstract ideas in real situations. Forth, they define analysis as the ability to break down complex problems into parts, solve each part and determine connections between parts. Fifth, they define synthesis as the ability to assemble parts in order to create a new whole, to integrate application knowledge with other skills, and to solve open-ended problems. Finally, the sixth step is defined as the ability to evaluate or judge design, solution to problem and presentation. Designing engineering online courses integrating all the aforementioned steps into an online platform can be a challenging task. As stated in [22], online engineering education requires that the quality of online courses must be comparable to or better than the traditional classroom. Also, the courses must be available when needed and accessible from anywhere, by a number of learners. Furthermore, topics across the broad spectrum of engineering disciplines should be available.

Recent advances in ICT technologies have generated significant interest across the research community, underlining the potential of laboratory-based learning through traditional classrooms or within an e-learning and/or a blended learning context [11,23,24]. There are also some studies that not only emphasise the importance of technology, but also examine the techniques for capturing, modelling and automating the on-campus laboratory tutors' knowledge [23]. Modern highly technological educational approaches such as remoteness (remote labs), virtuality (virtual labs) and recently immersion (augmented reality labs) [24], can greatly impact the traditional methods of teaching and in the case of the traditional hands-on labs alleviate drawbacks such as high costs, limited availability, maintenance, etc. Selecting out the right educational tools for delivering the curriculum, can address some of the reasons for not wanting to study engineering listed in Table 1. For example, setting up such remote laboratories featuring mixed reality technologies, can improve the use and reuse of the laboratories allowing more students to benefit from a more flexible timetable of study (Table 1—Point 3), as well as significantly reduce the running costs for the educational organisations (Table 1—Point 2) that maintain these laboratories. In addition, the online system can dynamically assess the educational level of the student and provide individualisation and differentiation of instruction (Table 1—Points 1 and 4). It is clear that technologically advanced laboratories can offer numerous benefits to both students and educational institutions but most importantly, this might be a crucial element for increasing attractiveness in the engineering discipline [25].

3. Methodology

The study reported here has been conducted in two stages. The first stage was a survey on Engineering Attractiveness to identify and disseminate the good practices employed by Universities. The study was carried out within the context of the Academic Network of European and Global Engineering Education (EUGENE), a Network funded by the European Union with the aim of improving the impact of European Engineering Education on competitiveness, innovation and socio-economic growth in a global context. The second stage, was carried out in the form of interviews, focusing on the distance learning implementation in Engineering Education.

3.1. Study on Attractiveness

A line of activities was formulated within the project that examined the concept of attractiveness of engineering studies within the European educational area. One of the main objectives of these activities was to identify and disseminate the good practices employed by universities in order to attract students to engineering disciplines and degrees. A pan-European survey-based research methodology was designed and implemented for this purpose. In particular, the methodology that was followed involved the development and administration of a questionnaire, aiming to capture information on the policies and/or activities employed by academic institutions currently offering engineering degrees within the European educational area, in order to attract students to their engineering degrees. While the use of individual attractiveness practices in the implementation of engineering studies has been extensively discussed and evaluated, this study was the first survey of the practices actually employed by academic institutions for this purpose that has been reported in the literature, to the best of the authors' knowledge.

A model for investigating attractiveness in engineering education, illustrated in Figure 1 was developed, so as to guide the construction of the questionnaire. This model depicts all stages of engineering education, the studies leading to them, the career paths of engineering students, and the respective feedback paths leading back to engineering studies.

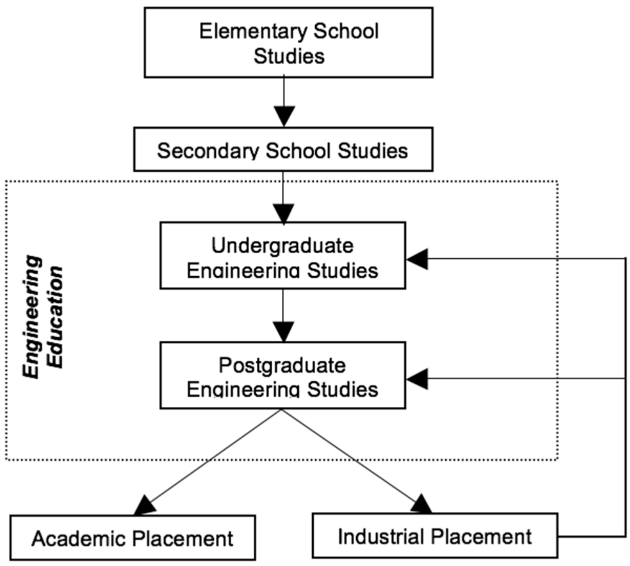

Figure 1. Model for investigating attractiveness in engineering education employed in the study.

The questionnaire distinguished between two categories of attractiveness: attractiveness-oriented activities (i.e., specific, purpose-based actions taken in order to increase the attractiveness of engineering studies), and attractiveness-oriented policies (i.e., strategic directions followed in order to increase the attractiveness of engineering studies). The questionnaire specifically inquired academic institutions on the target group, main objectives, means of implementation, source of funding, and qualitative/quantitative results of the activity's/policy's implementation. The questionnaire was submitted electronically to all academic institutions (n = 76) in the EUGENE network. A total number of twenty (n = 20) academic institutions across Europe offering engineering degrees completed and returned the questionnaire providing relevant information regarding the implementation of attractiveness activities/policies. Once all information was collected, a percentage analysis was conducted for each of the categories included in the questionnaire. Qualitative data, collected through the inclusion of several open-ended questions within the survey, were also analysed using qualitative means of analysis.

3.2. Distance Learning in Engineering Education

At the second stage of the study, five participants among those completing the questionnaire, originating from five different Higher Education (HE) institutions in four EU countries (Cyprus, Portugal, Serbia, Spain) volunteered to be interviewed. These academics were first asked whether they think their institution does take advantage of the benefits and proliferation of distance education to increase attractiveness of engineering studies. They responded positively, indicating that many of their undergraduate and/or post-graduate engineering study programmes are taught entirely at-distance or, at least, using a blended learning approach through use of the Learning Management System (LMS) such as Moodle.

In the following section, a short overview of the survey results is provided as they relate to distance-based education. More details regarding the study and its outcomes can be found in [19]. Furthermore, a brief analysis of the interviews is also provided.

4. Results

4.1. Basic Attractiveness Activities

The results related to the attractiveness activities implemented by academic institutions in order to increase the attractiveness of their studies are presented in Table 2. The analysis of these results (Table 2) reveals that academic institutions in Europe are mainly concentrating on increasing the attractiveness link between secondary school studies and engineering studies. Traditional advertising tools, such as TV, radio, and World Wide Web advertising, as well as face-to-face communication are employed for this purpose in the majority of cases (more than 90% of responses).

Table 2. Type of activity employed for attracting students to Engineering studies.

Activity	Percentage
Traditional advertising (newspapers, magazines, radio programmes, television)	93.33%
Secondary school/Elementary school visits	93.33%
University career oriented talks	33.33%
Public career oriented talks	40.00%
Other	26.67%

A closer examination of the survey results for this question revealed a wealth of activities employed by academic institutions in order to increase the attractiveness link between secondary school studies and engineering studies. In particular, academic institutions extensively seek to initiate face-to-face communication with secondary school stakeholders through a variety of either campus-based or remote activities:

4.1.1. Campus-Based Activities

1. Information sessions organised in the University for prospective students;
2. Information sessions organised in the University for parents;
3. Information sessions organised in the University for mathematics and science teachers;
4. Open days organised in the University for the general public;
5. Guided visits to the University premises for prospective students;
6. 'Test-driving' activities (controlled participation of prospective students in University studies, in the form of conducting experiments).

4.1.2. Remote Activities

1. Presentation of Bachelor degrees in secondary school premises;
2. Participation in University road shows.

Although the bulk of the activities concerns secondary students, there are also some initiatives targeting younger learners, such as children's university activities organised in the university for elementary school students.

Despite the wealth of activities employed by academic institutions in order to increase the attractiveness link between secondary school studies and engineering studies, none of these institutions carried out activities where distance-based learning was explicitly targeted as the main attractiveness element for the implementation of engineering studies.

4.2. Basic Attractiveness Policies

The results of the survey identified a small but still considerable number of institutions (15%), which follow policies that explicitly target the long-term increase of the attractiveness of engineering studies. In particular, the policies reported were the following:

1. Implementation of Quality Assurance (QA) techniques;
2. Incorporation of research knowledge and experimentation in teaching;
3. Investment on the development of state-of-the-art laboratories;
4. Focus on guaranteeing job placement for university graduates;
5. Active promotion and support of student welfare;
6. Acquisition of accreditation for degrees;
7. Implementation of the EFQM Excellence Model.

As with the case of attractiveness activities, no institution explicitly sought to utilise/implement policies related to the offering of distance-based engineering studies in order to increase their attractiveness. As an example, it is interesting to note that while many academic institutions invest heavily on the development of state-of-the-art physical laboratories, the development and use of virtual/remote laboratories was not reported as a significant policy towards increasing the attractiveness of engineering studies.

4.3. Funding Sources of Attractiveness Practices

Table 3 presents the survey results related to the funding sources employed by academic institutions for the practical implementation of their attractiveness activities/policies. These results indicate that the overwhelming majority of academic institutions use internal funding sources for the implementation of the corresponding activities/policies.

Table 3. Source of funding for attractiveness activities/policies.

Source of Funding	Percentage
Internal funding (University—Engineering School)	93.33%
External funding (Industry, benevolent)	33.33%
Government Support (Including military support)	46.66%

However, a significant percentage of institutions also utilise external funding resources, namely the government (46.6% of institutions) and the industrial sector (33.3% of institutions). This fact indicates that there is a general societal interest in increasing the attractiveness of engineering studies, possibly triggered by the worldwide lack of qualified engineers, as explained in the introductory section of this paper.

4.4. Funding Sources of Attractiveness Practices

The activities/policies described in the previous subsections can be used to target various engineering studies stakeholders. The survey inquired academic institutions about the stakeholders who are explicitly targeted through attractiveness activities/policies. The results of this part of the survey are presented in Table 4.

As expected, the majority of the attractiveness efforts are concentrated on secondary school students, who constitute the main target group of the relevant/policies activities. However, it is important to note that a significant percentage of institutions actively target students of elementary schools, aiming to promote the engineering discipline from a very young age. This focus on primary school children stems from the fact that the early years of schooling are especially important for children's academic development [19]. As the research suggests, students' identity is formed in the elementary grades, and predicts their attitudes and achievement in mathematics and science in later years [26]. Moreover, it is evident that due to the organic relationship that young learners now possess with the use of IT technologies, they will be much friendlier to the idea of implementing distance-based engineering studies in the near future.

Table 4. Target groups of attractiveness activities/policies.

Target Groups	Percentage
Elementary School Students	26.67
Secondary School Students	93.33
Undergraduate Students	46.67
Postgraduate Students	6.67
PhD Students	0.0
Mature Students (People who wish to change their working discipline)	13.33
Parents	53.33
Secondary School Teachers	46.67
Teachers/Instructors	66.67

4.5. Quality Objectives of Attractiveness Activities/Policies

The survey also inquired institutions on the quality objectives of their attractiveness activities/policies. The results of this part of the survey are summarised in Table 5.

Table 5. Quality objectives of attractiveness activities/policies.

Activity/Policy Objective	Percentage
Show that the engineering discipline is fun	46.67
Show that an engineering career is financially attractive	40.00
Show that the engineering discipline is useful for society	60.00
Show that engineering is a creative discipline	86.67
Show that the engineering discipline has global relevance	53.33
Show that engineering is a problem-solving discipline	80.00
Show that engineering is about collaboration & teamwork	20.00
Show that engineering is not only mathematics and physics	6.67
Show that engineering is integrated with ICT	6.67
Show that engineering demand is increasing	6.67

Results of Table 5 indicate that a significant percentage of attractiveness efforts aim to showcase the creative and problem-solving dimensions of the engineering discipline. This is not an unexpected result since, as already discussed in previous sections, attractiveness efforts are mainly directed towards the younger generations of people, who, in principle, are more interested in the 'excitement' generated by a discipline rather than its future career implications. Still, a significant percentage of efforts aim to underline the financial attractiveness of the engineering career, especially in relation to the implementation of postgraduate and continuous education studies.

It is interesting to note though, that very few of the attractiveness efforts aim to depict the 'interdisciplinarity' of the engineering profession, even if this is only confined to the closely-related field of ICT. This is a surprising finding, since 'interdisciplinarity' of subjects is considered to be a significant future research and teaching direction on a globalised level. The expected rise in the use of distance-based educational tools will undoubtedly strengthen the 'interdisciplinarity' dimension of engineering studies and therefore considerably increase their attractiveness.

4.6. Interviews on Distance Education in Engineering

Five participants, originating from five different HE institutions in four EU countries (Cyprus, Portugal, Serbia, Spain) volunteered to be interviewed. These academics were first asked whether they think their institution does take advantage of the benefits and proliferation of distance education to increase attractiveness of engineering studies. They responded positively, indicating that many of their undergraduate and/or post-graduate engineering study programmes are taught entirely at-distance or, at least, using a blended learning approach through use of the Learning Management System (LMS) such as Moodle. Nonetheless, only one noted that their engineering programmes develop and utilise "*remote experiments in engineering laboratories for distance experimenting*".

Interviewees indicated the percentage of undergraduate courses offered at-distance in their engineering programmes. They gave percentages ranging between 5–70%, noting that some of these courses were electives, while others were core, compulsory engineering courses. They also all stated that some of their online courses were lab-based.

Participants were also prompted to indicate what they consider as the main benefits of teaching engineering courses at-distance. They referred to the flexibility and convenience associated with distance education, which makes it possible for students to determine their own place, pace, and time of study: "*Students have the opportunity to study at a time and a place that suits them*". The promotion of communication and collaboration among students was also an aspect considered as an important strength of distance education: "*Students can consult teachers and their peers over online communication channels*". They also argued that the distance education option has important benefits not only for students, but also for the academic institution itself: "*Saves space and energy for the university*"; "*Attracts students living outside our region*"; "*Makes better use of equipment*".

At the same time, respondents identified a number of challenges in teaching engineering courses at-distance. Their biggest concern was the "pedagogical adequacy of materials and instructional approaches" used in distance education courses. In particular, they considered the "*realisation of lab-based classes*" to be a very difficult endeavour. The sole participant whose institution uses virtual laboratories also stated the need *to* "*improve the sense of real experimentation for the students taking remote experiments*".

Interviewees pointed out a number of measures taken at their institution to ensure that their online engineering programmes are of comparable, or even superior, quality to those offered face-to-face:

> "We try to follow up-to-date guidelines from specialists in distance education. We also use feedback from students, and we compare their grades with conventional classes";
> "We use remotely controlled laboratory exercises";
> "We try to raise awareness of the faculty to the specific difficulties of the at-distance model";
> "We regularly administer questionnaires that are used to measure the quality of our courses, and we carefully analyse their results."

When asked whether the engineering courses offered online in their university provide similar opportunities for interaction and collaboration between students and instructors and among students to those offered face-to-face, four of the interviewees agreed, stating that their distance education students "*can use various online communication channels such forums, videoconferencing, skype, and e-mail to communicate with their teachers and peers*". However, one of the participants pointed out that to promote and sustain communication and collaboration among students enrolled in courses taught entirely online, instructors ought to make participation in discussion forums and other collaborative activities a compulsory element of the course. This does not seem to be an issue in blended courses since, as the interviewees mentioned, *students "still have face-to-face interactions with instructors and between themselves"*.

Interviewees' responses suggest that their engineering programmes have still not been impacted by recent technological developments outside the education sector, such as Virtual Reality (VR) and Augmented Reality (AR). Only one respondent noted that they are "*in the process of introducing VR and AR in some online courses beside the courses in Computer animation study program where they are already in use*". The rest stated that there are currently no efforts at their institution to introduce VR/AR in engineering programmes, although "*these technologies are used by some instructors, more for research purposes*".

Only two of the respondents stated that their institution has empirical data on the impact of distance education on engineering students' motivation and learning. One of them noted that they "*have conducted some research among students concerning their motivation*", and the other one that they have also "*published some papers on that topic*".

Interviewees were finally prompted as to whether they considered distance education courses to be equivalent to or better than on-campus courses. One interviewee disagreed, considering them to be of lower quality compared to face-to-face courses, and noting that their institution faces a higher attrition among students taking online engineering programmes. This person argued that instructors teaching online should do more "*to attract students with more interesting materials, activities, foster their communication and collaborative work*". The rest of the respondents considered online courses to be of equivalent quality, pointing out, however that "*this is subject to the preparedness and readiness of teachers, the quality of the course material, and the level and competence of students in e-learning*". They stated that at their institution "*the dropout rate is observed not to be related to the at-distance model*", and that the typical feedback received by engineering students enrolled in online courses "*in general is very positive*". Moreover, they stressed that the academic performance of students enrolled in Distance Learning Courses is "*equally good*" to that of students enrolled in similar courses offered face-to-face.

The results from our survey and interview based methodology depicted that the academic institutions in the European educational area mainly utilise traditional forms of advertising and target predominantly secondary school students through internally-funded attractiveness activities/policies. However, a range of innovative attractiveness activities/policies are starting to emerge from these institutions, in an attempt to increase the efficiency of the attractiveness efforts. In terms of distance education in higher education, it is evident that many of undergraduate and/or post-graduate engineering study programmes are taught entirely at-distance or, at least, using a blended learning approach through use of the Learning Management System (LMS) such as Moodle. Furthermore, it was indicated that institutions offering distance education in engineering, do take advantage of the benefits and proliferation of distance education to increase attractiveness of engineering studies. At the same time, they have some reservations in regards to the way the material is being delivered along with the effectiveness of the instructor. It has also been deduced from the interviews, that there seems to be little effort in incorporating new technologies such as VR/AR/MR in delivering distant courses.

We next provide some recommendations as to how institutions could enhance these efforts by focusing on the potential of distance education. We first present tools that could be employed in distance learning engineering education, and then outline some ongoing or recently completed research projects related to distance education in engineering with emphasis given on remote laboratories.

5. Distance Learning in Engineering Education

Currently, the majority of online engineering degrees are available at the postgraduate level. One possible explanation is because undergraduate engineering degrees involve a great deal of laboratories that are too complicated or too expensive to run online. Another reason is because young undergraduate learners tend to prefer on-campus studies, unlike more mature adults who are more likely to study at a distance. Nevertheless, the quest for establishing fully online engineering degrees continues, with many academic institutions being involved in research and development of remote laboratories.

5.1. Tools Employed in Distance Learning Education in Engineering

Distance education relies heavily on Information and Communication Technologies (ICT). Offering online courses or even degrees requires a variety of technologies, which support both synchronous and asynchronous communication. Figure 2 illustrates some of the basic areas that must be addressed using ICT tools. These tools can be part of a general Learning Management System (LMS) such as Moodle, or they can be offered as independent tools possibly linked with the LMS employed for delivering the courses. Their functions can be briefly described as follows:

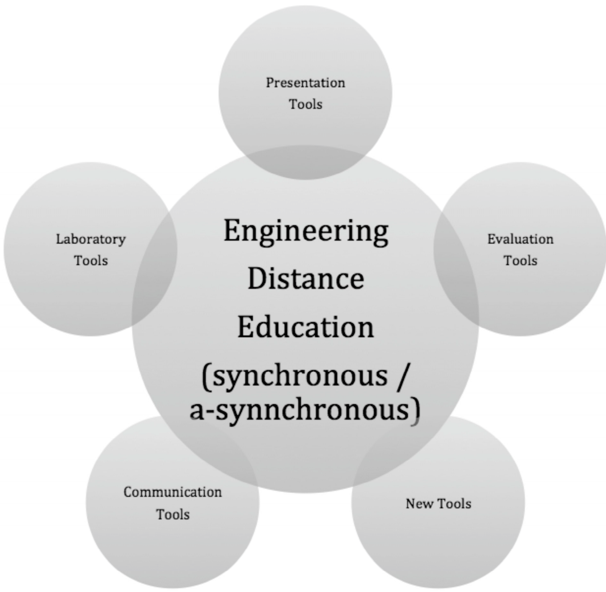

Figure 2. Engineering Distance Education Tools.

Presentation Tools: Synchronous presentation tools are tools that deliver the teaching material through audiovisual tools. Through these tools, the instructor can deliver the teaching material/notes while there is a bi-directional interaction between the instructor and the students or just between the students currently online. Asynchronous presentation tools usually provide access to recorded presentations from synchronous presentation sessions as well as typical PowerPoint presentation files. Tools such as Blackboard Collaborate, Webex, Skype and many others, offer the option to record synchronous presentation sessions and make them available for those unable to attend the "live" class at the time of its delivery.

Communication tools: Synchronous communication tools involve tools that support real-time discussion, either audio-visual or just text-based. Such tools are sometimes integrated with presentation tools and can be used in parallel to the presentation. In asynchronous communication, the exchange of messages does not happen in real time but at different time instances. Examples include the messaging system that any LMS features, emails etc. To put into perspective, what is required for engineering degrees to be made available online, a set of tools have been identified and presented below.

Evaluation tools: Although many of the online courses require students to undertake face-to-face examinations, students are still required to submit their assignments, projects etc. online. Synchronous evaluation tools require students to perform a test at a particular time using a particular tool (multiple choice exam, audio-visual online experiments, etc.). Using asynchronous evaluation tools, students can submit their work at any time (before the set deadline). Course evaluation can be done through various means, including simple homework, group-projects, multiple-choice questionnaires, all submitted electronically.

Laboratory tools: Engineering distance education, especially at an undergraduate level, requires that students have regular hands-on laboratory experience. Some experiments can be conducted using virtual tools, while others require tools that control real equipment in real time. Experiments related to disciplines such as electrical and electronic engineering, civil engineering, mechanical engineering and many other engineering degrees, dictate that engineering students must be able to remotely carry out these experiments. Failure to do so increases the risk of making distance learning engineering degrees inferior to the conventional ones. Examples of real time experiments using real or virtual equipment enhancing their operation with Augmented Reality (AR) technologies are currently an active area of research. An overview of the state-of-the-art in the field of Laboratory-based education can be found in [24] where the paper presents various technologies available in the area of Augmented Reality (AR) and the trend in education towards the use of different types of labs in the field of STEM. As it arises from [27], there is an obvious trend in STEM education towards the use of different types of remote laboratories. This trend creates the need for systematic research in order to answer the critical research questions that emerge, as mentioned in the previous sections.

Modern educators, irrespective of the level of education they are involved in, seek ways of providing the most effective, reliable and convenient tools and services for distance learning solutions. Some of the most widely used tools, listed by Steinberg [28], can be associated with delivering online material for engineering degrees. These are listed in Table 6.

Table 6. Distance Learning Tools.

	Tools	Description
1	Adobe Connect [1]	Offers immersive online meeting experiences from small group collaboration to large-scale webinars. Features digital meetings with various associated tools, an all-in-one webinar solution for marketers and a complete digital learning solution for trainers.
2	Blackboard [2]	Another educational tool consisted of various platforms (e.g., blackboard learn, collaborate, connect, mobile, analytics), which provide a virtual learning environment, featuring real time online collaboration environment that everyone can engage into a discussion.
3	Canvas [3]	A freely available learning management system that offers open, online courses taught by educators everywhere. Teachers, students, and institutions worldwide can use canvas to connect and chart their own course for personal growth, professional development, and academic inquiry.
4	Coursera [4]	An online portal used for hosting courses from universities around the world that gives students the chance to "attend" classes they would otherwise not have access to.
5	Dessci [5]	Combines a set of products for scientific and technical communication. Some of their available products are MathType, MathFlow, and MathPlayer software which are used by scientists, engineers, educators and publishing professionals, for authoring and publishing mathematical notation in print and online documents, and for building web pages with interactive math content.
6	edX [6]	One of the leading sites for accessing massive open online courses. Offers classes from various prestigious institutions, as well as material from an expanding list of partners.
7	ePals [7]	Another tool for enabling teachers to use the free ePals Global Classroom and create real world, culturally- enriching learning experiences for their students. For example, a class studying Chinese can connect with a class studying English in China, or the classes can work together on a special project, thus allowing classroom matching. Also allows teachers to create their own projects or join another class' existing ones.
8	FaceTime [8]	Employed by Apple users to make video calls between apple devices. Among the simplest and most widely-available ways to connect via voice and video with others online (provided they are using apple products).
9	Google Plus Hangouts [9]	A solution available from Google for connecting people via voice and video as well as chat, letting teachers, students and third-party experts to easily videoconference in groups.

Table 6. *Cont.*

	Tools	Description
10	Fathom Dynamic Data Software [10]	Enables users to freely and creatively explore ideas in mathematics, statistics, and science. Can be employed to relate studies to real-world examples and use the results to visualise and understand the concepts.
11	Tinkerplots [11]	A project funded by the National Science Foundation which led to the creation of a software tool and accompanying curriculum materials for teaching data analysis and statistics. The software offers a construction set rather than a menu of ready-made graph types, and helps orient students and teachers to the inquiry-driven nature of data analysis. Although originally targeting middle school children, it has also been widely used in high school and college level classrooms.
12	iTunes U courses [12]	Enable teachers to give each class a customised learning experience, through the creation and management of their own courses. Students can access it all from the iTunes U app without setting foot in a formal classroom.
13	Schoology [13]	Allows teachers to manage their classroom, engage their students, find resources, and connect to other teachers anytime, anywhere. Schoology features mechanisms with emphasis on the monitoring and education of students. This gives an additional tool to teachers by helping them analyse and better educate kids based on usage and activity.
14	Skype [14]	One of the most widely used tools for making voice or video calls as well as chatting, file exchange etc. Free and compatible with most available operating systems whether these are computers, smartphones, tablets, etc.
15	Udacity [15]	Another major player in the massive open online courses as it offers accessible, affordable, interactive online courses that seek to empower their students to advance not just their education but also their careers in technology. Courses, providing the most relevant and cutting-edge tech education that bridges the gap between academia and the needs of the 21st century workforce, are developed and offered in collaboration with leaders in the tech industry. All Udacity courses provide free access to the course materials, but in some of the courses users are given the option of paying a fee to enroll for the full course experience, gaining special access to projects, code-review and feedback, a personal Coach, and verified certificates.
16	YouTube [16]	Is effectively a library of videos, some of which are educational. There are numerous examples of leading schools and academic institutions posting material online through YouTube.

Notes: [1] http://www.adobe.com/products/adobeconnect.html; [2] http://www.blackboard.com; [3] http://www.instructure.com/; [4] https://www.coursera.org/; [5] https://www.dessci.com; [6] https://www.edx.org/; [7] http://www.epals.com/; [8] http://www.apple.com/mac/facetime/; [9] http://www.google.com/+/learnmore/hangouts/; [10] http://concord.org/fathom-dynamic-data-software; [11] http://www.srri.umass.edu/tinkerplots-project. [12] http://www.apple.com/education/itunes-u/; [13] https://www.schoology.com/; [14] http://www.skype.com/; [15] https://www.udacity.com/; [16] http://www.youtube.com/.

All these online educational platforms, communication tools, LMS, etc. can be used to deliver educational material. Some of them might target students at secondary education, some in higher education and some are general platforms that can be used by anyone. The main objective they all share is to deliver effective online education that can be practical, inspiring, easy to use and, above all, effective in knowledge transfer and creation. For the engineering discipline however, although being useful, these tools might not be sufficient. Engineering education combines science and mathematics based—subjects. These are traditionally hard to teach online because of the need for laboratories and equation manipulation [29]. For this to be addressed, there are two approaches. One is by employing virtual hands-on laboratories and the other by employing expensive laboratory equipment maintained at one location, accessed by all remotely. A more cost-effective solution is to carry out the laboratory sessions through summer programmes [30]. As a first approach, this can be used as a basic model for delivering engineering degrees online. Nevertheless, the overarching aim of distance learning is to enable students to attend a fully online degree without having to physically attend the class or the laboratory. The following section describes recent worldwide efforts in offering real time hands on experience on real equipment.

5.2. Distance Education in Engineering: Current Projects

Universities around the globe have been gradually replacing their conventional courses with online courses. The ninth annual survey of online education [31] states that the 10 per cent growth rate for online enrolments far exceeds the 2 per cent growth in the overall higher education student population. Nonetheless, offering online courses in engineering can be technically challenging. As stated by Fallon [32] in his paper "Survey of Existing Remote Laboratories used to Conduct Laboratory Exercises for Distance Learning Courses", several of the online courses (mostly in engineering/science) have a laboratory component that requires the use of hardware and/or software, posing technical problems or even licensing problems when operated remotely. If the laboratory component is purely software based, then minimum constraints are expected, except perhaps in the case where centralised applications or license servers are used.

Engineering laboratories intended for distance learning are primarily hardware-based, with access to the laboratory equipment being either physical or virtual. As stated by Fallon [32], access to such laboratories can be realised through a specialised lab kit, a Virtual Private Network (VPN), or the creation of strategically located remote learning centres. Each approach is employed depending on the type of the laboratory that will be designed, and is associated with particular technical challenges and costs. Müller and Erbe [33] differentiate engineering laboratories between hands-on and virtual (simulated), local and distributed, and mono-user or multi-user environments and present the idea of a remote laboratory as a laboratory that enables students to access physical laboratories or workbenches from distance sites by using a suitable communication infrastructure.

Some institutions that offer online courses and programmes, have chosen to avoid remote laboratories altogether perhaps because costs are too high or the number of students enrolled in these courses does not justify the deployment of such laboratories. Other institutions have invested time and money to develop such laboratories. Table 7 presents various projects around the world that are related to remote laboratories. Some are designed for students in higher education and some in secondary education. Despite of context, the design and implementation of such laboratories is always interesting and sometimes inspiring when developing a new laboratory for a new course.

Table 7 lists a number of remote laboratory implementations identifying the technical issues towards the specific implementation of an architecture to fulfil the educational requirements of each experiment. The format, the equipment used and the complexity of the lab delivered is dictated by the curriculum. In some cases, hardware equipment must be setup and remotely accessed—which means that there is an added technical complexity and cost to the remote laboratory. In these cases, the remote labs are not as well integrated as the ones that are mostly software based. Furthermore, cost restrictions affect the integration between the modules (hardware control mechanisms and LMS) and limit the capacity in terms of user access—thus posing usage restrictions of the remote laboratories. Security is also an issue that needs to be considered in cases where sensitive and expensive equipment is being used, but most importantly the LMS needs to safely keep the records of the students and their results.

Table 7 indicates that there is a great variety of equipment, mechanisms and methodology employed targeting different pools of students. It also suggests that there is no optimal architecture and it is important that each laboratory exercise is implemented in such a way that the learning outcomes are fully addressed.

Table 7. Distance Learning Projects and Technologies Employed.

	Project Name	Institution/Location	Scientific Field	Technology Used	Description
1	UTS remote laboratories—the Programmable Logic Controller (PLC) laboratory, and the water level laboratory	Faculty of Engineering at the University of Technology, Sydney	Mechanical Engineering	PLC rigs/electro-pneumatic cylinders, iSightTM firewire webcam, RSLogix programming environment	These laboratories are designed for mechanical and mechatronic engineering students, and have been used in the teaching of subjects such as "Advanced Manufacturing", "Dynamics and Control" and "Mechatronics 2" [34].
2	Heat Transfer Remote Laboratory	Georgia Institute of Technology, Savannah, USA	Mechanical Engineering	LabVIEW®, Armfield® HT10XC Computer Controlled Heat Transfer station, an Armfield® HT15 Extended Surface Heat Exchanger	An experiment was created to obtain experimental data and analyse the ability of Remote Labs to be integrated with current coursework. Surveys results indicated that the perceptions a student carries about the effectiveness of Remote Laboratories improves after they perform the experiment [35].
3	Remote operations of High Angular Resolution Astronomy centre	Georgia State University, Atlanta, USA	Astronomy	Linux-based workstations, archival server interfaced to the main control computers of the array via a Virtual Private Network (VPN) over the Internet	The telescope array is located atop Mount Wilson, California northeast of Los Angeles. Through this collaboration, the telescope was possible to be remotely controlled from the Arrington Remote Operations Centre (AROC), located on the campus of GSU in Atlanta, Georgia. This has enabled faculty and students to remotely operate the array from Atlanta and has led to a significant reduction in travel costs of the people involved. This project evolved into four more remote operations facilities established in France, Australia and the US [32].
4	Laboratory in the Department of Telecommunications and Signal Processing	Blekinge Institute of Technology (BTH), Sweden	Electrical Engineering	National Instruments (NI) PXI-1000B 8-slot #U PXI, (PXI-8176), four plug-in boards, two function generators (PXI-5411 and PXI-5401), an oscilloscope (PXI-5112), a digital I/O board (PXI-6508), server system running LabVIEW	A remotely operated laboratory accessed from around the world for delivering exercises for courses in electrical engineering. The remote laboratory is implemented using a 'remotely controlled switch matrix with five nodes, ten branches, and 40 components, two function generators, a digital multi-meter, and an oscilloscope' [36].
5	Remote Laboratories for the SPSU campus	Southern Polytechnic State University (SPSU) and Technical College System of Georgia (TCSG), USA	Engineering Technology	Lab Kits accessed through Virtual Private Network (VPN) over the Internet	SPSU and TCSG have been working together towards enabling students to complete laboratory exercises at facilities that are remote to the SPSU campus [32].
6	Canadian Remote Sciences Laboratories	Northern Alberta Institute of Technology (NAIT) and Athabasca University, Canada	Engineering Technology		Remote laboratories designed were based on the control of analytical instruments in real-time via an Internet connection. Students perform real-time analysis using equipment, methods, and skills that are common to modern analytical laboratories (or sophisticated teaching laboratories). Examples of experiments developed are Chromatography and Spectroscopy [37].
7	ECU virtual laboratory	East Carolina University, USA	Computer Science/Engineering	Virtualisation software VMware workstation, Linux and Windows Servers	A virtual laboratory environment consisting of virtual machines, which communicate with one another over a virtual network. Students are able to run these machines "remotely" on their own computers at home [34].

Table 7. *Cont.*

	Project Name	Institution/Location	Scientific Field	Technology Used	Description
8	NeReLa (Building a Network of Remote Labs for strengthening university secondary vocational schools collaboration)	Europe (Eight Serbian partners and five European institutions took part in this project)	Electronic, Electrical, Mechatronic and Computer Engineering	Varying from Nexys 2 FPGA platform and Xilinx ISE Design Suite, to CompactRIO, CeyeClon platform, raspberry pie and thermocouple sensors	A European Funded project (Tempus) completed in 2016. The wider objective of this project was to increase attractiveness of engineering education through innovative teaching methods, as well as through strengthening of university and secondary vocational schools' collaboration. Some of the specific objectives listed in NeReLa [38] were to build a cross-universities network of remote engineering laboratories in order to enhance engineering education at Serbian Higher Education institutions and to strengthen university-secondary vocational schools collaboration through secondary vocational school teacher training in using resources of The Library of Remote Experiments (LiReX). Furthermore, NeReLa aimed to bring remote engineering experiments into secondary vocational school classrooms in order to promote engineering education attractiveness to prospective engineering students.
9	Go-Lab Project (Global Online Science Labs for Inquiry Learning at School)	Secondary Education/Europe	Science—Secondary Education	Remote and virtual science labs, inquiry learning applications, and Inquiry Learning Spaces (ILSs) together with an authoring tool for teachers to create own ILSs.	It was completed in 2016, focused on secondary education, aimed to open up remote science laboratories, their data archives, and virtual models ("online labs") for large-scale use in education. Go-Lab [39] enables science inquiry-based learning that promotes acquisition of deep conceptual domain knowledge and inquiry skills and directs students to careers in science.
10	PEARL (Practical Experimentation by Accessible Remote Learning)	Europe	Science and Electronic and Manufacturing Engineering Education	Motorised Optical Spectrometer, Computer Vision Experiment Rig, Apache based web server, video cameras, Goepel digital I/O board, function generator board, multimeter board, two-channel 100 MHz oscilloscope	An EU funded project completed in 2003 that aimed at enabling students in conducting live experiments over the web providing high quality learning experiences in science and engineering education by bringing the teaching laboratory to the students, giving flexibility in terms of time, location and special needs [40].
11	EL-STEM (Enlivened Laboratories within STEM Education)	Secondary Education/Europe	STEM Secondary Education	AR environment, Unity Programming Tools	An Erasmus+ funded project that has started in October 2017 and it aims to develop a new approach, inspired by the emerging technologies of AR (Augmented Reality) and MR (Mixed Reality) with Remote and/or Local Laboratories, for encouraging 12-18 year-old students' STEM engagement. In particular, EL-STEM's main objectives are to (a) attract students who currently might not be interested in STEM related studies/careers and enhance the interest of those who have already chosen this field of studies/careers, (b) improve students' performance in courses related to STEM [41].

6. Discussion and Conclusions

This paper has explored the potential of distance education approaches as a means of tackling the well-documented trend in recent years of declining interest in the pursuit of engineering studies and careers. Specifically, the article first presented the current situation in relation to European universities' efforts to increase the attractiveness of their engineering programmes, as this emerged through the conduct of a survey study. It then analysed a number of interviews on how distance education can be used in engineering in order to provide an alternative to conventional education using advanced ICT technologies. Based on the study findings, it then offered some suggestions as to how these efforts could be enhanced through the incorporation of the distance learning component as an alternative to conventional education.

The results of the survey study highlighted the lack of a distance-learning dimension in the implementation of engineering studies in the European Area. Although the number of students enrolled in online engineering courses/degrees steadily increases every year, academic institutions continue to focus their advertising efforts on attracting students to their traditional, face-to-face programmes. None of the institutions participating in our study carried out activities where distance-based learning was explicitly targeted as the main attractiveness element for the implementation of engineering studies although some of them have been using distance based education to deliver their engineering courses.

Undoubtedly, to remain competitive and to increase their attractiveness, academic institutions offering engineering degrees ought to take advantage of the undisputed benefits and proliferation of distance education along with the new trends in remote laboratories, VR, AR and MR. At the same time, however, they should take measures to ensure that their online engineering programmes are of comparable, or even superior, quality to those offered face-to-face. The existing literature indicates not only advantages, but also challenges regarding distance education, and variable effectiveness of distance education programmes [42]. While most of the conducted studies show that students taking online courses have similar achievement and satisfaction levels compared to students in traditional, face-to-face classrooms [43,44], there is growing evidence of many web-based distance learning courses failing to meet the expectations raised. This has been suggested in the interview based study presented in Section 4. For example, while it is well-documented in statistics education research that the incorporation of discussion and active learning in the classroom can help learners to think and reason about statistical concepts, bringing these important learning approaches to an online course has proved very challenging [45,46].

Early attempts at Internet-based instruction assumed that setting up an attractive website with interesting online and multimedia applications, was adequate for learning to take place. It is now recognised that the level of success of a distance learning course is determined by multiple factors, such as underlying theory, technologies, teaching strategies, and support for learners. Elements in the design of a web-based course such as the content and structure of the course, the presentation of the online materials, and the amount of interaction between instructors and learners as well as among learners are important factors affecting students' learning and attitudes [47]. Another important criterion for the level of success of network-based engineering training is the extent to which instruction allows learners to tackle realistic problems related to their field of study, or their daily life [48].

In addition to the general issues and considerations regarding distance education, the training of engineers at a distance poses special challenges that also ought to be taken into account when designing an online engineering programme. Although there are numerous support platforms to develop online courses, very few of them were designed specifically to carry out remote experiments in a real laboratory using real and not virtual equipment e.g., [38]. There have been various attempts from various academic institutions to design remote laboratories for educational purposes, and some examples of these initiatives have been presented in this paper. The main challenge is to offer hands-on experience to students by physically accessing laboratories or workbenches from distance sites, enhancing their user experience with new technologies such as Augmented or Mixed reality supported by a suitable communication infrastructure. This model can be considered successful, if the industry accepts the graduates from the distance education programmes in the same way they do for the conventional ones—considering them equally qualified for the job. There have been substantial efforts towards the development of such technologies, but there is still a long way to go for engineering degrees to be successfully offered online in their entirety. However, it is expected that as more and more academic institutions realise the importance of online education and join forces to work towards higher standards, more cost effective, high quality platforms for delivering physically accessible laboratories or workbenches from distance sites will begin to appear.

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