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A Comparative Analysis of Worldwide Trends in the Use of Information and Communications Technology in Engineering Education

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ABSTRACT This paper forecasts learning technologies that are predicted to impact the practice of engineering education according to the perceptions of engineering education researchers and practitioners. These forecasts were derived from three worldwide surveys carried out in 2013, 2014 and 2015. The responses were analyzed to know the technologies that will have an impact in the short, medium and long term. In turn, differences in forecasts according to area of specialization and geographical region were studied. Moreover, this paper applies social analysis (Google Trends) and bibliometric analysis (Google Scholar, Scopus and Web of Science) to these predictions in order to discover which technologies were successful and really impacted in engineering education, and which ones failed to have the predicted impact and why.

INDEX TERMS Engineering education, higher education, worldwide survey, technology-enhanced learning, technology meta-trends.

I. INTRODUCTION

Information and communication technologies have a powerful influence on all aspects of modern society, from commerce and business to health and entertainment. Obviously, education is not an exception. There are various references and bibliographic sources in which experts predict which technologies will be the most relevant in future education. Probably the most internationally accepted studies in this field are the New Media Consortium Horizon Reports [1]. They predict the impact of emergent technologies on education across the world in three time frames (short, medium and long term). Martin [2], [3] conducted a study over the Horizon Report predictions to find out future meta-trends in learning-enhanced technologies. The Horizon Reports focus on general educational trends and do not focus specifically on the needs of engineering educators in higher education. However, engineering educators may require different technologies than the ones used in general education.

Because few studies have focused in on the more technical and practice-oriented disciplines, such as STEM and engineering education [4]–[6], the New Media Consortium (NMC) launched a series of reports in 2012 and 2013 that focused on analyzing STEM+ educational technologies called ''Technology Outlook for STEM+ Education. An NMC Horizon Report Sector Analysis''. These reports analyzed the STEM+ sector in both 2012-2017 [7] and 2013-2018 [8] periods. The reports highlighted some differences from the more general Higher Education editions. For example, the STEM+ reports considered as very relevant technologies more practice-oriented technologies such as virtual and remote labs. No reference to these technologies was made in the Higher Education global reports.

Educational research in engineering is a diverse field. Many researchers explore and create theoretical contributions in engineering cognitive psychology, engineering learning

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models, and engineering classroom techniques [9]–[14]. Another set of researchers actively pursues the development of information and communications technology to support and enhance the deliverability of engineering content to both traditional students attending residential universities as well as remote learners at distant locations [15]–[20].

Many successful technologies have had an impact on engineering education and significantly changed the way that students learn. For example, computer simulation is now standard practice in most engineering education disciplines [21], [22]. Similarly, learning management systems have been adopted by many universities as a technique to modularize the learning experience, provide asynchronous learning supplements, and provide a tracking mechanism to monitor student flow through coursework [23], [24].

It is important for education technology researchers to understand the current research trends in learning technologies, as well as the perception of both teachers and students about these technologies. In this respect, to our knowledge, the opinion of engineering professors and students about the use of information and communication technologies has been mainly studied from a regional perspective [25]–[27] and, therefore, it becomes necessary to have studies that provide a global overview of the perceived impact of technologies in engineering education.

Bibliometric studies have been also used to analyze trends, to identify emerging technologies and to assess their impact in higher education through time [28]–[30]. The potential of Google Trends to measure the interest in specific terms and to assess predictions made by experts has been demonstrated [3]. However, the assessment analysis of the social interest of educational technologies has only started to be used in engineering education. This can be documented by the fact that the search for "Google Trends" in the IEEE Xplore database only recovered forty-six bibliographic records consisting of 42 conference papers and 4 articles. In addition, the Education Resource Information Center, also known as ERIC, indexed only seven bibliographic records.

Thus, the main objective of this work was to identify technology meta-trends based on perceptions of engineering education researchers and practitioners and to evaluate whether these perceptions are reflected in the social interest and the scientific impact over time.

The paper is structured in four main parts: an introduction; a methodology section, which describes the stages of the study; a results section, which includes a compilation of the data obtained from the survey and its relationship to the social interest and the academic impact; and a conclusions section, which provides the main findings, in addition to the guidelines for further development and research.

II. METHODOLOGY

The study methodology included data collection from community surveys, analysis of the data, and objective assessment of the results. The methodology used previously by Martin [2] was adopted because it addressed the study requirements well, being both studies dedicated to the analysis of the impact of technologies in education among time. The four main stages of the research were survey creation, assessment of the social interest, determination of the scientific impact and data analysis. Each of these stages is outlined in this section.

1. The first stage was the creation and administration of the survey. The survey collected the following information from each engineering education community participant: country of residence, a prediction of the three most important technologies that will impact the education of students in the participant's engineering field, a prediction by the participant of when each of the three chosen technologies would be implanted in education with the choices (a) 1 year or less, b) 2-3 years, and c) 4-5 years), and finally the challenges or requirements needed to get the technologies to truly make an impact. This stage involved the following tasks:

   1.1. The first task was to compile a list of important technologies to provide as possible answers in the survey. Three main sources were consulted. First, technologies were obtained from the topics of major international education conferences including the ASEE/IEEE Frontiers in Education Conference (FIE), the IEEE Global Engineering Education Conference (EDUCON), the ASEE Annual Conference, the AACE Global Conference on Learning and Technology (Global Learn), the AACE Global Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA), and the AACE Society for Information Technology and Teacher Education International Conference (SITE). Second, technologies were also obtained from three of the most cited engineering education journals: the IEEE Transactions on Education, the IEEE Transactions on Learning Technologies, and the ASEE Journal of Engineering Education. Finally, technologies were obtained from the Horizon Reports (Johnson, 2010), which provide a glimpse of the most likely technologies to impact higher education in the near future.

   1.2. The second task was to define the list of challenges or requirements needed to get the technologies to truly make an impact: a) Better understanding of new ways of interacting with students, b) Creativity in designing learning experiences, c) Development of better technology infrastructures, d) Maturity of the technology, e) More funds to further development and implantation, and f) New pedagogical methodologies that apply to the technology.

   1.3. The third task was to create a computer-based application to administer the survey.

1.4. The fourth task was to define the electronic mailing lists to distribute the survey. For this study, the selected participant groups were the memberships of the IEEE Education Society, the ASEE Engineering Technology Division (ETD), the ASEE Engineering Research and Methods Division (ERM), and the registered authors and participants of the IEEE EDUCON conference.

1.5. The fifth task was the submission of the surveys to the defined electronic mailing lists. The survey was applied three times: 2012, 2013 and 2014. A total of 15 technologies were included the first year, 4 more were added in 2013 and, finally, one more technology was added in 2014 (Appendix 1). A total of 618 participants responded to the survey in 2012, 439 participants in 2013, and 375 participants in 2014. Tables 1 and 2 show the distribution of the sample sections by area of specialization and geographic region.

2. The second stage was to assess to which extent the participants' perceptions were consistent with social interest. The social interest was measured by means of the relative search volume (RSV) provided by Google Trends. Searches with this instrument were carried out on 20th June 2019. The following search criteria were used for each of the 20 technologies: a) time limit: three years before and after administration of the survey (for example, for a technology asked on the 2012 survey, the interval was from the 1st January 2009 to the 31st December 2015); b) geographical limit: no geographical limitation was defined; c) search categories: the search was limited to the categories ''Education'', ''Colleges & Universities'' and ''All categories''. Using these categories, three measures of interest of these terms were obtained worldwide: the overall interest, the interest in the context of education and in the context of higher education.

3. The third stage was the bibliometric analysis. The scientific impact was assessed by analyzing the number of scientific studies published on said technologies in Google Scholar, Scopus and in Web of Science. With Google Scholar we could examine a number

TABLE 1. Distribution by area of specialization.

	Computer Science and Software Engineering	Electrical and Computer Engineering	Engineering Education	Mechanical and Industrial	Telecommunication	Other
2012	19.9%	37.5%	21.0%	6.8%	5.0%	9.7%
2013	23.9%	36.7%	20.7%	4.8%	7.3%	6.6%
2014	14.4%	34.4%	14.4%	14.4%	3.7%	18.7%

TABLE 2. Distribution by geographic region.

	Africa	Asia and Oceania	Europe	North America	South America
2012	2.6%	14.9%	35.0%	31.7%	15.8%
2013	3.1%	17.6%	36.5%	25.8%	16.9%
2014	2.5%	12.8%	26.7%	35.7%	22.3%

TABLE 3. Educational technologies forecast in the period 2012-2014.

	2012	2013	2014
3D printing	-	4.02%	8.36% (2nd)
Augmented reality for learning	4.64%	3.80%	3.02%
Cloud computing	6.53%	6.61%	6.49%
Digital accreditations	-	1.75%	1.24%
E-books and digital libraries	11.38% (2nd)	8.35% (2nd)	8.18% (3rd)
E-learning platforms and architectures	12.84% (1st)	11.16 % (1st)	9.69% (1st)
Games & virtual worlds to foster student's engagement and motivation	3.99%	4.86%	3.56%
Gesture-based computing	0.70%	0.68%	0.80%
Intelligent tutoring system	-	-	4.71%
Interactive video lectures and video conferencing	7.12%	5.54%	5.78%
Learning analytics and semantic web	3.72%	4.02%	2.31%
Learning objects reusability and digital repositories	3.88%	3.26%	2.76%
MOOCs	-	7.97% (3rd)	6.58%
Mobile and ubiquitous technologies for learning	10.46% (3rd)	7.59% (4th)	7.02%
Open source, open standards, and federated systems	5.72%	3.80%	4.09%
P2P online assessment	-	1.14%	0.89%
Remote labs	5.88%	5.69%	5.60%
Simulators	8.41% (4th)	6.99% (5th)	7.91% (4th)
Virtual labs	7.50% (5th)	6.99% (5th)	6.31% (5th)
Web 2.0 tools and social networks for learning	7.23%	5.77%	4.71%

Note: The five most important technologies for each category are shaded.

TABLE 4. Adoption of educational technologies.

	2012			2013			2014		
	< 1	2- 3	4-5	<1	2-3	4-5	<1	2-3	4-5
3D printing	-	-	-	17.0%	47.2%	35.8%	31.9%	48.9%	19.1%
Augmented reality for learning	11.6%	40.7%	47.7%	18.0%	34.0%	48.0%	5.9%	55.9%	38.2%
Cloud computing	33.1%	50.4%	16.5%	36.8%	44.8%	18.4%	45.2%	39.7%	15.1%
Digital accreditations	-	-	-	8.7%	52.2%	39.1%	7.1%	64.3%	28.6%
E-books and digital libraries	46.4%	44.1%	9.5%	49.1%	35.5%	15.5%	53.3%	32.6%	14.1%
E-learning platforms and architectures	52.5%	34.9%	12.6%	52.4%	34.0%	13.6%	55.0%	30.3%	14.7%
Games & virtual worlds to foster student's engagement and motivation	25.7%	33.8%	40.5%	25.0%	34.4%	40.6%	25.0%	42.5%	32.5%
Gesture-based computing	15.4%	23.1%	61.5%	11.1%	22.2%	66.7%	0.0%	44.4%	55.6%
Intelligent tutoring system	-	-	-	-	-	-	7.5%	50.9%	41.5%
Interactive video lectures and video conferencing	35.6%	46.2%	18.2%	45.2%	42.5%	12.3%	35.4%	43.1%	21.5%
Learning analytics and semantic web	15.9%	58.0%	26.1%	18.9%	47.2%	34.0%	19.2%	46.2%	34.6%
Learning objects reusability and digital repositories	34.7%	47.2%	18.1%	41.9%	32.6%	25.6%	32.3%	35.5%	32.3%
MOOCs	-	-	-	33.3%	39.0%	27.6%	31.1%	47.3%	21.6%
Mobile and ubiquitous technologies for learning	33.0%	51.0%	16.0%	43.0%	41.0%	16.0%	43.0%	45.6%	11.4%
Open source, open standards, and federated systems	43.4%	27.4%	29.2%	30.0%	50.0%	20.0%	41.3%	28.3%	30.4%
P2P online assessment	-	-	-	20.0%	53.3%	26.7%	30.0%	10.0%	60.0%
Remote labs	24.8%	41.3%	33.9%	30.7%	44.0%	25.3%	28.6%	44.4%	27.0%
Simulators	50.0%	34.0%	16.0%	53.3%	29.3%	17.4%	50.6%	29.2%	20.2%
Virtual labs	28.8%	41.7%	29.5%	30.4%	45.7%	23.9%	29.6%	39.4%	31.0%
Web 2.0 tools and social networks for learning	60.4%	29.9%	9.7%	65.8%	28.9%	5.3%	66.0%	24.5%	9.4%

Note: The highest response rate for each of the technologies in each year is shaded.

of multidisciplinary academic repositories, such as "Springer", "IEEE Xplore", "Wiley Online Library", "JSTOR", "ERIC", and Questia. It also enabled us to access the libraries of several universities around the world, and even academic social networks such as Mendeley. In contrast with the globality of Google Scholar, the search in Scopus and Web of Science was also chosen, namely the prestigious and selective databases called Scopus, SCI, SSCI and A&HCI. In these cases, the following search criteria were used: a) time limit: three years before and after publication of each technology to obtain the history of publications for each keyword; b) publication field: the search was narrowed down to education-related publications, by selecting publications with the keywords "learning" or "education" anywhere in the article in Google Scholar, and in the topic in Scopus and Web of Science (topic searches include the following fields within a record: title, abstract and keywords). The reason for analyzing data from 2012, 2013 and 2014 in 2019 is because this gap is needed to be able to analyze the bibliometric impact of these predictions among time.

4. The fourth stage was the analysis of the worldwide results. A descriptive approach was adopted to analyze which technologies are considered most important by the participants. Secondly, from a nonparametric perspective, differences in the responses according to area of specialization and geographical region were examined. For this purpose, Pearson's Chi-square test was applied. Finally, the Spearman correlation coefficient was used to determine the correlation between the importance attached to the different technologies, their social interest and their scientific impact over time. Spearman correlation is appropriate when variables are not normally distributed, and the sample size is small ($n < 30$). Because the technology list only included 15(2012), 19(2013), and 20(2014) items, the value of n is 15, 19, and 20. Thus, the following formula was applied:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2 - 1)}$$

where n is the number of data pairs and di is the difference between the ith pair of ranks [R(Xi)-R(Yi)].

III. RESULTS

A. ASSESSMENT OF THE MOST IMPORTANT TECHNOLOGIES AND THEIR IMPACT ON EDUCATION

Table 3 presents the technologies that participants considered most important in each of the three years analyzed. The results show that there was a high correlation between the valuations given in the different years (rs12-13 = 0.941 [p. 0.000], rs12-14 = 957 [p. 0.000], and rs13-14 = 0.856 [p. 0.000]). E-learning platforms and architectures appears in all cases as the technology that would have the greatest impact on education, followed by E-books and digital libraries and, in 2014, 3D printing.

On the question of when the technologies were going to be implanted in education (Table 4), once again, there was a high stability among the results obtained in the three editions. The experts highlighted the imminent impact of the following technologies within a one-year time frame: e-books and digital libraries, e-learning platforms and architectures, open source, open standards, and federated systems, simulators, and web 2.0 tools and social networks for learning. Eight technologies were considered to have the greatest impact in the medium term (between 2 and 3 years) in 2012. Of these, only cloud computing is valued by experts as a technology that would have an impact in the short term (less than one year) in 2014.

About the challenges or requirements needed to get the technologies to truly make an impact, in general terms, a similar trend was observed in the three editions (Figure 1). The main challenges or requirements was identified as follows: creativity in designing learning experiences, new pedagogical methodologies that apply to the technology and better understanding of new ways of interacting with students.

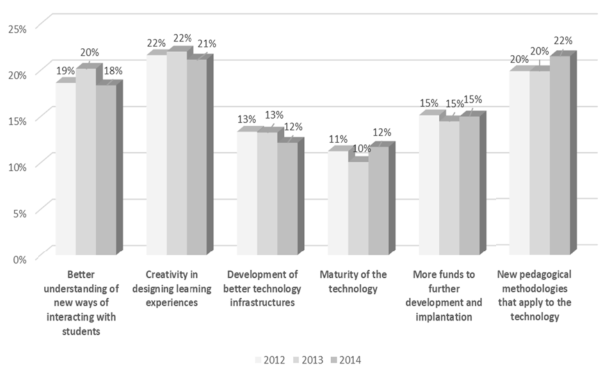

FIGURE 1. Challenges influencing technologies impact on education.

B. DIFFERENCES IN THE EXPECTED IMPACT OF THE TECHNOLOGIES ACCORDING TO AREA OF SPECIALIZATION AND GEOGRAPHICAL REGION

Considering the area of expertise, significant differences were observed in the assessment given to the technologies

TABLE 5. Most valued technologies according to area of specialization.

	2012	2013	2014
Mechanical and Industrial	1. Interactive video lectures and video conferencing (14.3%) 2. E-learning platforms and architectures (13.5%)	1. 3D printing (12.7%) 2. E-books and digital libraries (11.1%)	1. 3D printing (13.6%) 2. E-books and digital libraries (11.1%)
Electrical and Computer Engineering	1. E-books and digital libraries (13.8%) 2. Simulators (12.6%)	1. E-learning Platforms and Architectures (10.8%) 2. Massive Open Online Courses (9.5%)	1. Simulators (9.3%) 2. E-books and digital libraries (8.8%)
Computer Science and Software Engineering	1. E-learning Platforms and Architectures (14.6%) 2. Mobile and Ubiquitous Technologies for Learning (13.0%)	1. E-learning Platforms and Architectures (12.7%) 2. Mobile and Ubiquitous Technologies for Learning (12.1%)	1. Mobile and Ubiquitous Technologies for Learning / E-learning Platforms and Architectures (13.0%) 2. Cloud computing (8.6%)
Telecommunication	1. E-books and digital libraries / E-learning Platforms and Architectures (11.8%) 2. Remote labs (10.8%)	1. Simulators / Virtual labs (11.8%) 2. E-books and digital libraries / E-learning Platforms and Architectures / Interactive video lectures and video conferencing (9.4%)	1. Cloud computing / Massive Open Online Courses / Mobile and Ubiquitous Technologies for Learning / Remote labs (9.5%)
Engineering Education	1. E-learning Platforms and Architectures (14.6%) 2. E-books and digital libraries (11.5%)	1. E-learning Platforms and Architectures (11.4%) 2. E-books and digital libraries (7.7%)	1. E-learning Platforms and Architectures (11.7%) 2. Web 2.0 tools and social networks for learning (9.3%)
Other	1. E-books and digital libraries (17.8%) 2. E-learning Platforms and Architectures (11.7%)	1. E-learning Platforms and Architectures (12.6%) 2. Simulators / Virtual labs (9.2%)	1. E-books and digital libraries / Simulators (11.9%) 2. E-learning Platforms and Architectures (10.5%)

according to the specialization of the participants ($\chi^2_{2012} = 240.11$ [p. 0.000], $\chi^2_{2013} = 171.739$ [p. 0.000], $\chi^2_{2014} = 156.916$ [p. 0.000]). Considering the two main technologies that were selected by each of them (Table 5), it shows how the impact of 3D printing technology is especially considered by specialists in mechanical and industrial, and the mobile and ubiquitous technologies for learning was most valued by specialists in computer science and software. Finally, from the areas of electrical and computer engineering and telecommunication, more importance was given to simulators.

TABLE 6. Most valued technologies by geographic region.

	2012	2013	2014
Africa	1. E-learning Platforms and Architectures (13.3%) 2. E-books and digital libraries / Interactive video lectures and video conferencing / Mobile and Ubiquitous Technologies for Learning (11.1%)	1. Cloud computing (20.5%) 2. Simulators (12.8%)	1. 3D printing / E-learning Platforms and Architectures / Games & Virtual Worlds to foster student's engagement and motivation (11.1%)
Asia and Oc eania	1. E-books and digital libraries (13.8%) 2. E-learning Platforms and Architectures (11.9%)	1. E-books and digital libraries / E-learning Platforms and Architectures (11.0%) 2. Virtual labs (9.6%)	1. E-learning Platforms and Architectures (12.8%) 2. Massive Open Online Courses (7.8%)
Europe	1. E-learning Platforms and Architectures (14.2%) 2. Mobile and Ubiquitous Technologies for Learning (10.1%)	1. E-learning Platforms and Architectures (10.8%) 2. Massive Open Online Courses (8.4%)	1. E-learning Platforms and Architectures / Remote labs (8.8%) 2. Massive Open Online Courses / Virtual labs (8.2%)
North America	1. E-books and digital libraries (14.1%) 2. E-learning Platforms and Architectures (10.8%)	1. E-books and digital libraries / E-learning Platforms and Architectures (10.6%) 2. Massive Open Online Courses (8.4%)	1. 3D printing (12.2%) 2. Mobile and Ubiquitous Technologies for Learning (10.7%)
South America	1. E-learning Platforms and Architectures (14.1%) 2. Mobile and Ubiquitous Technologies for Learning (12.7%)	1. E-learning Platforms and Architectures (11.9%) 2. Mobile and Ubiquitous Technologies for Learning (9.5%)	1. Simulators (15.9%) 2. E-books and digital libraries (11.8%)

With respect to the geographical region (Table 6), in 2012 there were no significant differences in the valuation given to one or the other technologies ($\chi^2_{2012} = 70.851$ [p. 0.087]). However, in the 2013 and 2014 surveys, differences in the importance given to technologies according to geographical region were significant ($\chi^2_{2013} = 103.748$ [p. 0.008], $\chi^2_{2014} = 135.958$ [p. 0.000]). For example, in 2013, professionals from Europe and North America tended to give greater value to MOOCs, those from Asia, Oceania and North America to e-books and digital libraries, and those from South America valued most the mobile and ubiquitous technologies for learning. In 2014, experts from Africa and North America especially considered that 3D printing technology would have an impact on education and those from South America highlighted the role that simulators would play.

C. RELATIONSHIP BETWEEN THE EXPECTED IMPACT OF THE DIFFERENT TECHNOLOGIES AND THEIR SOCIAL INTEREST AND SCIENTIFIC IMPACT OVER TIME

Figure 2 represents the relationship between the expected impact for the different technologies and their social interest

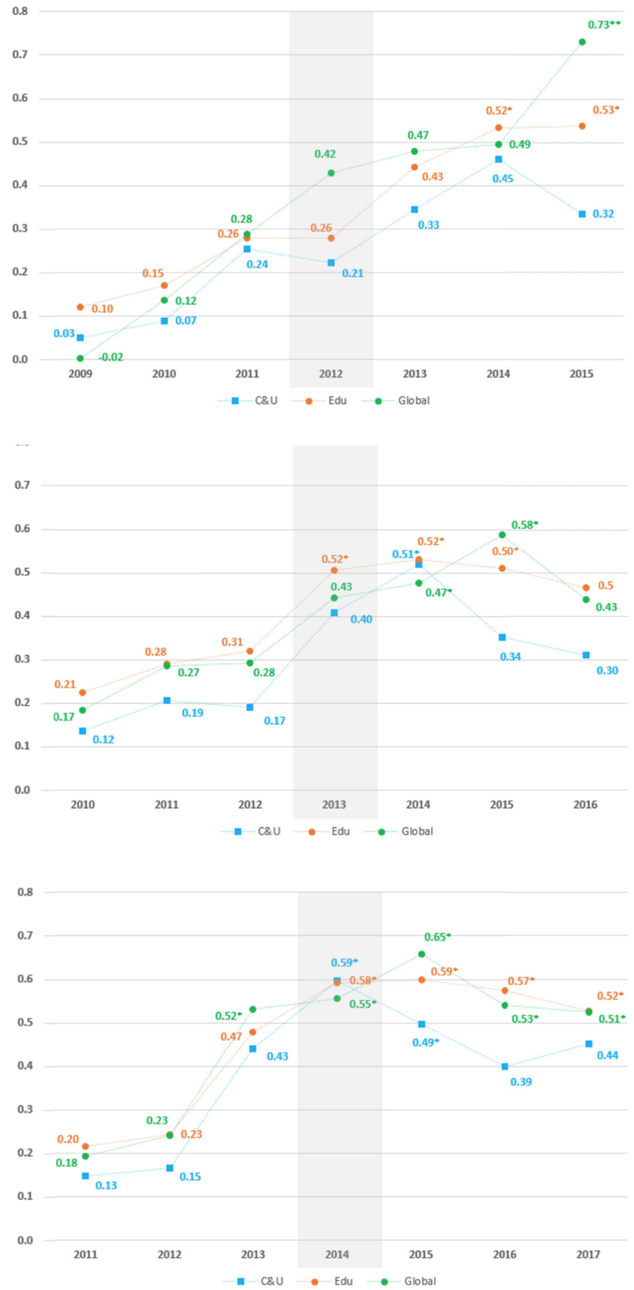

FIGURE 2. Relationship between the expected impact for the different technologies and their social interest over time.

three years before and three years after that prediction was made. As indicated above, social interest was considered in three Google Trends categories: Colleges and Universities, Education and Global. The results show an upward trend in the magnitude of this correlation, especially when the social interest is assessed globally or for the educational sector in general. For these two categories, the predictions made by the experts correlate significantly with the social impact that these technologies have subsequently had.

On the other hand, the results shown in Figure 3 reflect the relationship between the expected impact for the technologies and the amount of scientific production that, around them, is collected in the following databases: Google Scholar, Web of Science and Scopus. In general terms, a non-significant correlation was shown between both variables, the magnitude of the correlation coefficients hardly varies over time (before and after the prediction). Only the predictions made by participants in 2013 correlate with the scientific output collected in the Scopus database from that year onwards.

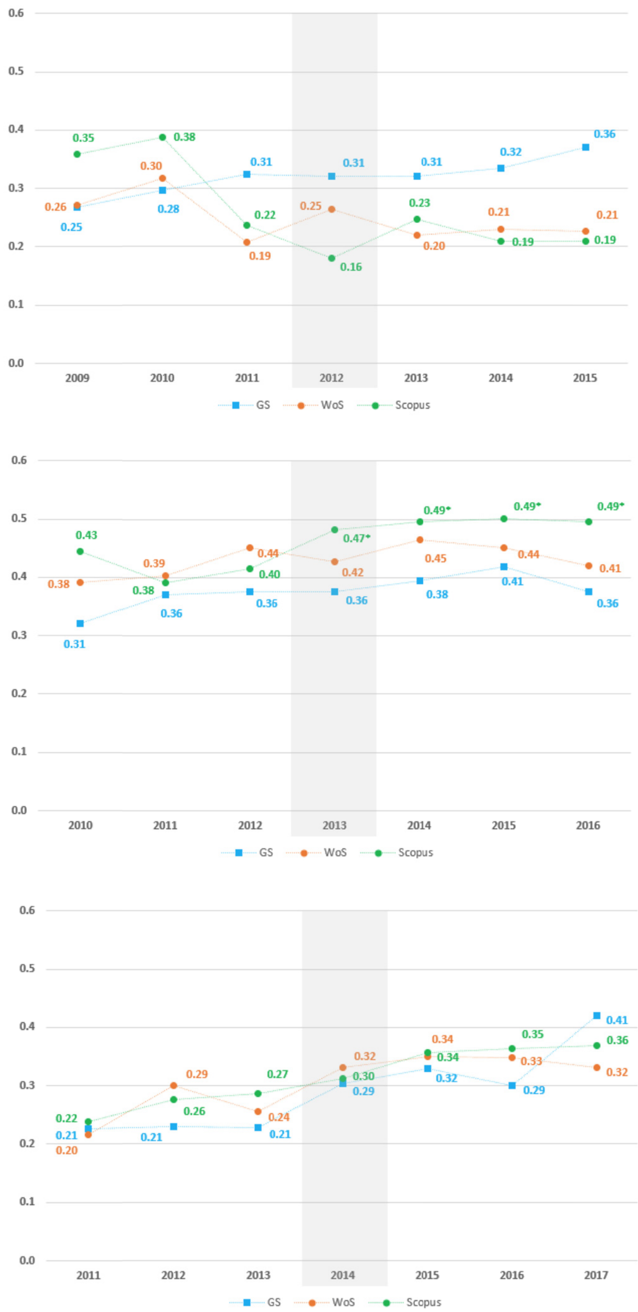

FIGURE 3. Relationship between the expected impact for the different technologies and their scientific impact over time.

IV. CONCLUSION

In this paper, we have analyzed the perceptions of engineering education researchers and practitioners on the educational technologies that are used in the day-to-day practice of engineering education. The results have confirmed predicted impacts for some technologies such as MOOCS, e-books and digital libraries, e-learning platforms and architectures, and mobile and ubiquitous technologies for learning, whose importance in higher education has been identified in previous studies [2] focused in general education. In addition, it has allowed discovery of other technologies which are playing a key role in engineering education, for example, simulators and virtual labs. By having data collected at three different times, it has made it possible to compare the response given over time. In this respect, high stability has been observed in the forecasts, with very high correlations between the results of the three years (even taking into account that participants have varied in the three surveys), which helps to guarantee the reliability of the predictions and suggests that the large sample sizes of each survey help control the effect of participants fluctuation.

Regarding when these technologies are expected to be implemented in education, the most valued technologies for the engineering education community participants tend to be those for which the most immediate impact is expected. This would lead one to think that the greatest degree of participant agreement could be affected, to some extent, by the immediate impact that these technologies may already be having on engineering education. At the same time, there is a high stability in the responses provided by participants during the three years. By way of example, for many of the technologies that were expected to impact in the medium term (2 or 3 years) in 2012, a medium-term impact continues to be forecast in 2014. These results suggest that the impact of these technologies on education is not something immediate, but it takes some time to have a real impact.

Moreover, this study highlighted the differences in forecasts according to area of specialization and geographical region. In the first case, the particularities of the discipline may have certain methodological implications and, in turn, require the application of specific technologies. With respect to the geographical region, the impact of the technologies on society or even the conception of engineering education in each region could be conditioning differences observed. In future work, it would be interesting to delve deeper into the contextual factors that might explain these results.

An important contribution of this work is that the predictions of a large community of engineering educators have been contrasted with the social interest and scientific impact of these technologies three years before and after the predictions were made. This makes it possible, in a way, to assess the success of the predictions. In relation to social interest, two conclusions can be made. First, the values for the correlation coefficients between the forecast and the social impact prior to those predictions being made, suggest that the assessments made by the experts reflect the upward trend in social interest. Second, the correlations with the social impact, three years after the predictions, were significant in most cases (fundamentally for the Education and Global categories), which suggest that the impact of these technologies foreseen for education could be extrapolated to other areas, such as Arts, Entertainment, Business, or Health.

In addition, it has allowed discovery that research activity does not follow the same curve as the social excitement generated by new technologies. In terms of scientific impact, the lack of a clear trend in the relationship between the forecasts and the scientific impact over time (before and after the prediction), could be explained by the fact that the study sample was composed not only of academics, but also of other professionals. In future research, this aspect should be considered in order to be able to analyze differences according to the professional field of origin.

Finally, another limitation in the trend analysis comes from the lack of transparency of the Google Trends methodology [32] and the limitation to the number of characters allowed in its query. The limitation in the number of characters allowed in the search equation also affects Google Scholar. In addition, other limitations are related to the design of information retrieval equations, conditioned by the need to limit the search in Google Scholar, Scopus and the Web of Science to educational publications, which may cause a loss of relevant works.

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