Stimulating Education about Standardization – Activities and perspectives of National Standards Bodies

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Abstract: Standardization is essential for business and society. However, many people remain unaware of this. Education about Standardization (EaS) would be one solution to increase awareness. EaS has been a topic of research for several decades. Literature suggests that National Standards Bodies (NSBs) can play a core role in stimulating EaS – but is this actually the case? This research aims to investigate what NSBs do in stimulating EaS and hear their perspectives on EaS. Based on the literature and insights from experts in the field, a survey was prepared and sent to NSBs. Next, stories behind the data were revealed during in-depth interviews with NSB experts. The results from 90 NSBs all over the world show that they believe there is a need for EaS and most of them have activities in this field. They also share insights about what should be achieved in the following years, potential solutions to reach their objectives, and the future of EaS. This article advances knowledge in the field of EaS, with a focus on the role, actions, and perspectives of NSBs. This work also provides suggestions on how NSBs can foster EaS together with other stakeholders. This is one of the first studies with a focus on NSBs in fostering EaS.

Keywords: Education about Standardization, National Standards Bodies, ISO, Strategy

1. Introduction

In recent decades, the value of standards has become widely recognized, and their scope has broadened to feature complex systems and sustainability. While this expansion makes standardization even more relevant, many stakeholders, including governmental and industry experts, know little about standards and standardization at strategic, tactical, and operational levels (European Commission, 2022). Indeed, previous research has identified a significant knowledge deficit among students and the general public with regard to standardization (e.g., Kanevskaia, 2020; Puiu, 2020; Vasileva, 2020). Education is the solution to such a knowledge gap, and indeed, policymakers have expressed the need for Education about Standardisation (EaS), e.g., the Asia Pacific Economic Cooperation (APEC, 2006) and the European Commission (2022). These policymakers recognize the role of NSBs in stimulating EaS. Academic research addressed the NSB role as well (D. Choi et al., 2009; H. J. de Vries, 2011; H. J. de Vries et al., 2014). Indeed, standards bodies have taken initiatives and reported these at conferences of the International Cooperation for Education about Standardization (ICES) and the Academic Days of the World Standards Cooperation (WSC – a cooperation between the

international standardization organizations ISO, IEC, and ITU). However, a systematic and up-to-date inventory of what these NSBs actually do and could do is not available. This research aims to fill this gap by investigating the perspectives and actions that National Standards Bodies (NSBs) have taken in EaS.

2. EaS Literature

The multi-disciplinary field of EaS has been evolving over the last few decades, and meanwhile, the literature covers a great variety of topics related to the theme. Several definitions exist for education and standardization. 'Standardization' can be understood more broadly than in the formal ISO definition. Therefore, we took the more general and scientifically underpinned definition by de Vries (1997, p. 161):

> Standardization is the activity of establishing and recording a limited set of solutions to actual or potential matching problems[1] directed at benefits for the party or parties involved, balancing their needs, and intending and expecting that these solutions will be repeatedly or continuously used during a certain period by a substantial number of the parties for whom they are meant (de Vries 1997, p. 161).

'Education' is the action or process of educating or of being educated. It is divided into formal education or pre-employment education and post-formal education or in-employment education. The former is split into four sub-categories of education: primary, secondary, undergraduate, and graduate. EaS aims to provide the knowledge and information necessary to understand what standards are, how the standardization system works, the impacts on business and society, the use of standards and, per profession, contribute to transforming awareness into specific actions.

Several attempts to effectively increase the EaS provided at schools and universities have been reported at the conferences mentioned, but Jachia et al. (2020), Kanevskaia (2020), Puiu (2020), Vasileva (2020), and de Vries (2020b); and de Vries et al. (2020) suggest that not much has changed in the last decades, and the systematic lack of awareness persists.

Academic authors have been looking at EaS from different perspectives. These include pedagogical approaches, curricula development, innovation, Sustainable Development Goals (SDGs), standard-specific courses, and case studies. Another interesting topic is the level of knowledge about standardization required by different stakeholders – for example, engineers should have more than just basic awareness (APEC, 2009; Cooklev, 2010; ISO, 2014; Van den Bossche, 2020). APEC (2019) presents a "career roadmap and competence requirements for standards professionals", providing guidance for professionals working in companies or Standards Development Organizations (SDOs). A similar document was published by IFAN (2018). These guides help define what different kinds of professionals should know, and the variety of contents proposed exemplifies the interdisciplinarity of standardization.

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[1] Matching problem: Problem of interrelated entities that do not harmonize with each other. Solving it means determining one or more features of these entities in a way that they harmonize with one other or of determining one or more features of an entity because of its relation(s) with one or more other entities.

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Once decided what professionals should know about standardization, students can get prepared for such a profession and role within an organization. Next, it is crucial to determine how to teach them about the subject. The most common pedagogical approaches for incorporating EaS into curricula found in the literature are the creation of engaging content, serious games or simulations, workshops, case studies, and intensive writing (e.g., essays, reports, critical reviews). As highlighted by APEC (2009), organizations must proactively evaluate the needs of their audience and utilize pertinent pedagogical practices for teaching about standardization. Practical examples include employing engaging and appealing content in informatics and information systems (Fomin, 2020), experiential and collaborative interdisciplinary learning in management education (H. J. de Vries, 2020a), engaging content based on real-world situations (Mijatovic, 2020), using hands-on case studies (Katusic et al., 2017), and the application of serious games in engineering education (Aydan et al., 2017; Calderón et al., 2018; García et al., 2020). It was also observed that while some academic programs include EaS as a specific discipline, most institutions integrate it into existing curricula.

EaS is needed, as mentioned in the literature, to improve the employability of the workforce (CEN & CENELEC, 2011), foster technological development (D. G. Choi & de Vries, 2013), and for helping to address the SDGs from a long-term perspective (H. J. de Vries, 2020a; Wright et al., 2020). However, the main systematic challenges for teaching EaS are the lack of academic centers (Kurokawa, 2015), standards courses (D. G. Choi & de Vries, 2013; Kurokawa, 2015), research in standardization (Mijatovic, 2020), financial support (D. G. Choi & de Vries, 2013), and adequate educational materials (Calderón et al., 2018; Fomin, 2020; García et al., 2020). This is compounded by difficulties related to institutional structures, students' academic backgrounds, and low overall public awareness (Fomin, 2020; Kurokawa, 2015).

When it comes to who should take the initiative and act to foster EaS, the literature suggests the SDOs (APEC, 2009, 2015; ISO, 2014; Pohle et al., 2018), but also governments (APEC, 2009), universities (Katusic et al., 2017), industry (Puiu, 2020) or even all of these stakeholders together (APEC, 2008; H. J. de Vries, 2014, 2020b; Jachia et al., 2020; Puiu, 2020). In this paper, we focus on the role of SDOs at the national level: NSBs.

3. Initiatives on EaS

Several initiatives to foster EaS have taken place worldwide in the last few years, at the global, regional, and national levels.

Firstly, there have been a number of activities at the international level. The European Academy for Standardisation (EURAS)[2] is the only international community of academic researchers in the field of EaS, and its objective is to study standardization as a phenomenon rather than focus on technical research related to specific standards (H. J. de Vries et al., 2020). EURAS published a White Paper on EaS (Hesser & de Vries, 2011) and supported EaS in other ways as well. Until recently, there was also the International Cooperation for Education about Standardization (ICES), which was established in Tokyo in 2006 and brought together experts from academia, industry and standards bodies on a yearly basis to share ideas and experiences

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[2] Despite the name, EURAS' membership is truly international and not limited to Europe.

about EaS (since the COVID-19 pandemic, these activities have ceased). The international SDOs, ISO, IEC and ITU, sometimes work together on activities related to EaS through their 'World Standards Cooperation (WSC)' and have organized past events such as WSC Academic Days and Roundtables. The three organizations have also taken action individually in EaS. For example, ISO has published a booklet on good practices for collaboration between NSBs and universities (ISO, 2014), promotes an annual research grant, maintains a repository of educational materials, actively collaborates with the University of Geneva, and has included EaS in its implementation plan for the ISO Strategy 2030 (ISO, 2021). China's Belt and Road (B&R) initiative (Anon. 2022) promotes EaS as well, on an international scale. In 2018, China Jiliang University initiated an annual event to promote international cooperation and exchanges for standardization, the Belt and Road University Alliance for Standardization Education and Academics (B&RUAS) (Anon. 2021). Since its establishment, 117 universities from 36 countries have joined B&RUAS. Other activities include forums and academic conferences.

Even intergovernmental organizations such as the United Nations have worked on EaS – the United Nations' Economic Commission for Europe (UNECE) Working Party on Regulatory Cooperation and Standardization Policies (WP.6) established a group called 'START-Ed' in 2012. Jachia et al. (2020) summarize the initiatives of UNECE on EaS and conclude that teaching approaches for EaS need to be reviewed; future works should focus on awareness building involving multiple stakeholders (including standards-setting bodies), support synergies and further cooperation, build capacity, tailor messages to different audiences, and look into new standards-related areas such as gender-responsive standards. In addition, governments should work in partnership with appropriate organizations and academia to encourage the inclusion of EaS in academic curricula, vocational education and training, and awareness-raising activities.

Secondly, at the regional level, work is ongoing by regional SDOs as well as intergovernmental forums. NSBs, as members of these groups, are directly engaged in this work. In Europe, the three European Standardization Organizations CEN, CENELEC, and ETSI founded, in 2010, the "Joint Working Group on Education about Standardization" (JWG-EaS), which elaborated a "Masterplan on Education about Standardization" to serve as a framework for EaS strategies at the European level and support NSBs in taking action (CEN & CENELEC, 2011). However, the group was disbanded in 2016 since some stakeholders preferred to address EaS as a national-level activity without European exchange, cooperation and support. In Asia, the Asia-Pacific Economic Cooperation (APEC) and the Korean Agency for Technology and Standards (KATS) jointly initiated a project entitled "APEC Strategic Standards and Conformance Education Program," which published its first deliverable in 2008 (APEC, 2008), produced by the Korean Standards Association (KSA). The objective was "to develop reference curricula and materials to address the significance of standards and conformance to trade facilitation in the region" (APEC 2008, p. 5). In total, six education guidelines were published (APEC, 2008, 2009, 2010, 2011, 2015, 2019).

Thirdly, there are initiatives from professors and educational institutions at the national level, and some of these national level activities are very advanced, as is shown in the recent book by Idowu et al. (2020). National initiatives can also be taken by NSBs. The book provides two cases of this: Bulgaria (Vasileva, 2020) and Romania (Puiu, 2020). Examples of NSB initiatives

in other countries include France (AFNOR, n.d.), Japan (JSA, n.d.), South Africa (Visser, 2012), and the UK (BSI, n.d.). Usually, these initiatives include guest lectures, the organization of public events, teaching materials (e.g., brochures), and training activities. However, in most NSBs, there is no data publicly available, or the data is difficult to access (e.g., no dedicated website for EaS initiatives and no reporting activities that include the topic of EaS).

Literature shows hardly any in-depth case descriptions of NSB EaS activities. An exception is the study by Choi and de Vries (2013) who mapped the developments and evolution of the University Education Promotion on Standardization (UEPS) in South Korea. UEPS aimed to incorporate EaS into science and technology education at the national level. The program was considered a success since thousands of students at all educational levels have participated in lectures about standardization. The activities were focused on developing a national strategic plan, the development of syllabus, textbooks, courses, publication of case studies, and teachers' training. Success factors were the NSB (KATS and KSA) leadership and their collaboration with universities, continuous improvement, the national plan-based approach, long-term funding from the NSB (in order to financially contribute to teachers' wages, provide free teaching materials, and helping with company visits and guest lectures), and a close relationship with all stakeholders involved. The remaining challenges were the dependency on public financing, the difficulty for professors to keep in touch with external speakers, training of teachers, and answers to questions such as if the UEPS courses actually helped students in their future career development.

In this work, it is assumed that EaS has not been adopted worldwide to the extent needed. This can be evidenced in the research previously mentioned as well as by observing the development of initiatives in the last decades. For example, De Vries and Egyedi (2007) presented the results of a workshop organized by the International Committee for Education about Standardization (ICES) which identified the state of art insights on EaS. They concluded that the increasing number of initiatives indicated momentum in EaS. Fifteen years after their work was published, it is possible to observe that many initiatives they mention, with many stakeholders involved and strong financing, have been discontinued without being replaced by new initiatives. The first example is the ICES itself which has not been active since 2020, although it was not officially disbanded.

A second example is that South Korea and other Asian countries were demonstrated as being active and advanced in EaS and several authors (e.g., Choi & de Vries, 2013; de Vries & Egyedi, 2007) had the expectation that the rest of the world would follow, to some extent, a similar model to foster EaS. Thus far, over a decade later, this has not happened (e.g., standardization courses are not systematically present at all educational levels). Also, in South Korea, the number of students reached per year has decreased. Even the thousands of students reached during the most successful years of the initiatives were a small fraction of the one million academic students in Korea.

Another example is the Master in "Standardization, Social Regulation and Sustainable Development", at the University of Geneva, which was reportedly the only one in the world to combine sustainability and standardization in a balanced way (Idowu et al., 2020, p. 213). It existed between 2011 and 2022, when it was reshaped to adopt topics judged to be more relevant to students after a systematic review of the curricula (Curtis et al., 2021). One of the

outcomes was the reduction of standardization components in the curricula – apparently these was seen as less relevant.

To conclude, EaS initiatives have been taken all over the world, but these reach only a fraction of the total number of students. Some initiatives have been terminated without replacement. Apparently academic recognition is an issue as well, and usually such recognition stems from the amount of attention given to the topic in academic research. Stimulating research on EaS is therefore one strategy to improve the recognition of this topic and convince academia about the importance of standardization.

In order to successfully foster EaS worldwide, several initiatives must happen simultaneously, with the involvement of a range of stakeholders at the national, regional, and international levels. We focus on the national level and particularly on NSBs since NSBs are, de facto, the bodies that enable the creation of standards and encourage their use at the national level. In addition, NSBs are the focus of this article because other bodies (e.g., regional SDOs) cannot intervene directly within the geographical domain of an NSB (e.g., develop activities in a specific country) without prior consent. Therefore, in practice, NSBs are the main actors that drive EaS development worldwide, each one in their country, with the support of regional and international SDOs. Additionally, EaS might be offered online at a global level, e.g. via MOOCS[3]. International and regional SDOs may play a direct role at this level.

4. Methodology

To collect data about EaS practices and observations, we interviewed professors, NSBs, and stakeholders from regional and international SDOs and other institutions, and distributed a web-based survey. Our methodology is inspired by several authors (Aydan et al., 2017; Forza, 2002; Garza-Reyes, 2015; Puiu, 2020) and a scoping exercise performed by the International Organization for Standardization Central Secretariat (ISO/CS) Research and Innovation (R&I) unit in 2020. We combine qualitative methods with quantitative elements. Figure 1 shows the project phases, their location in the study, the objectives of each phase, methods, and tools employed.
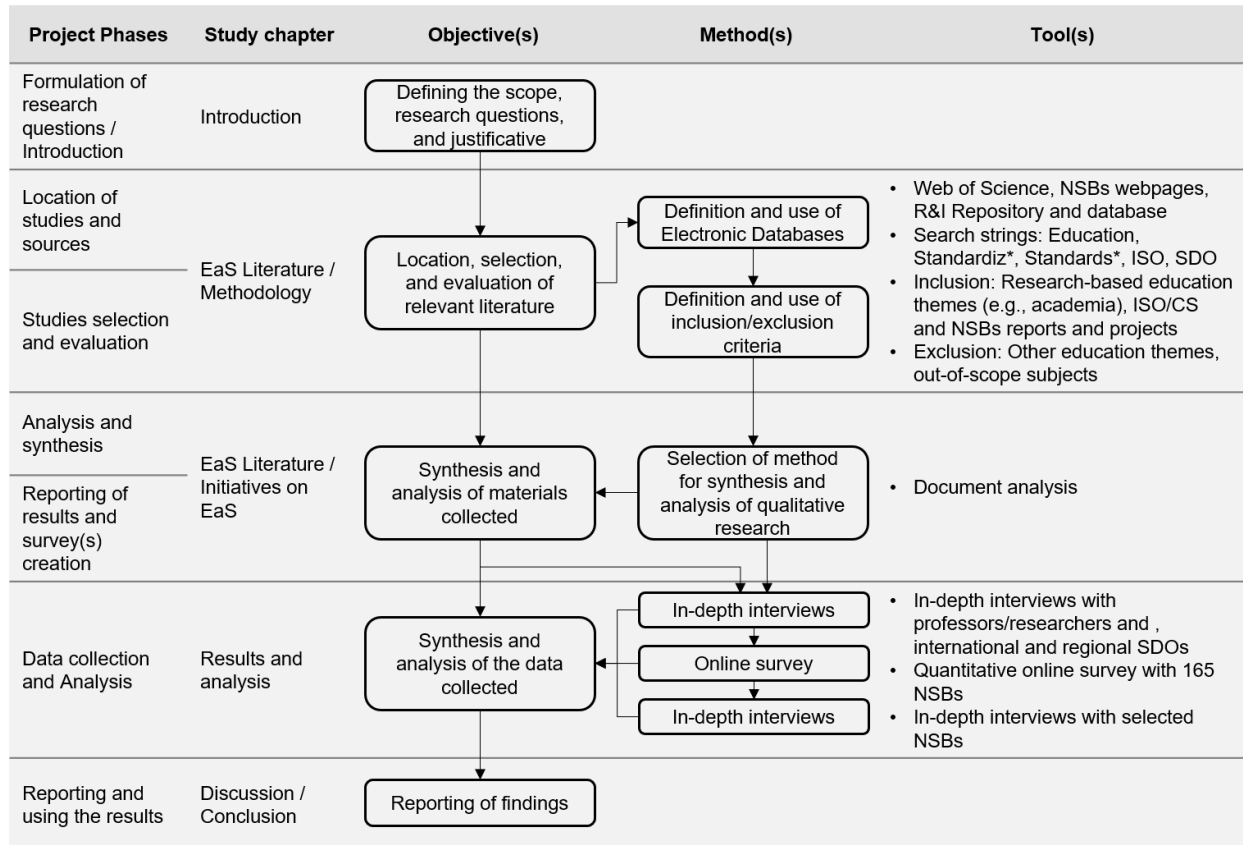
The formulation of the scope of our research started with a scoping exercise organized by the Research and Innovation unit of ISO's Central Secretariat, entitled the "Education workshop 2020". Ten EaS experts participated in this workshop, including professors, specialists in standardization, ISO/CS employees, and NSBs employees.

The location, selection, and evaluation of available studies were made through a systematic search in the electronic databases of Web of Science, Google Scholar, and the ISO/CS R&I unit database, with an overall methodology based on the suggestions of Garza-Reyes (2015). First, the Boolean search had the strings "education* AND standards*", then "education* and standardiz*", and other combinations of these keywords. Next, criteria for exclusion of articles were considered (e.g., out-of-scope subjects, articles more than 10 years old) by reading the summary of the articles. Finally, the second selection of papers was performed, looking at the

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[3]E.g., https://www.mooc-list.com/tags/standardisation

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Figure 1 – Methodological framework

Project Phases	Study chapter	Objective(s)	Method(s)	Tool(s)
Formulation of research questions / Introduction	Introduction	Defining the scope, research questions, and justificative		
Location of studies and sources	EaS Literature / Methodology	Location, selection, and evaluation of relevant literature	Definition and use of Electronic Databases	• Web of Science, NSBs webpages, R&I Repository and database
Studies selection and evaluation			Definition and use of inclusion/exclusion criteria	• Search strings: Education, Standardiz*, Standards*, ISO, SDO • Inclusion: Research-based education themes (e.g., academia), ISO/CS and NSBs reports and projects • Exclusion: Other education themes, out-of-scope subjects
Analysis and synthesis	EaS Literature / Initiatives on EaS	Synthesis and analysis of materials collected	Selection of method for synthesis and analysis of qualitative research	• Document analysis
Reporting of results and survey(s) creation				
Data collection and Analysis	Results and analysis	Synthesis and analysis of the data collected	In-depth interviews / Online survey / In-depth interviews	• In-depth interviews with professors/researchers and , international and regional SDOs • Quantitative online survey with 165 NSBs • In-depth interviews with selected NSBs
Reporting and using the results	Discussion / Conclusion	Reporting of findings		

references of the articles selected, the database of the ISO/CS R&I unit, and ISO's repository of teaching materials (ISO, n.d.). In this search for literature, we did not just focus on the role of NSBs, we took a broader scope. The information gathered from these articles included: the relevance of EaS, EaS challenges, emerging EaS topics, proposed solutions for fostering EaS, course topic or proposal, a summary of the proposal for the activity, learning outcomes, audience, pedagogical approaches used, type of knowledge, and teaching topics, and data about the authors (e.g., filiation, email). On top of this, we screened proceedings of conferences of the European Academy for Standardization EURAS and the International Cooperation on Education About Standardization ICES in the years since 2010.

The document analysis and synthesis, plus the findings of the scoping exercise, led to the elaboration of the online survey and interview guidelines. The online survey was further adapted according to the results of the data collection phase 1 explained below.

The data collection and analysis were based on Forza's (2002) three distinct data collection phases for survey research and on the knowledge acquired in the R&I scoping exercise:
1. In-depth semi-structured interviews via videoconference to assess and map current initiatives related to EaS while looking for the perspectives, insights, and recommendations from ISO/CS current and former employees, professors, and

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international and regional SDOs. This assessment and mapping are the basis for elaborating the survey with NSBs.

2. Web-based survey to identify and map current projects related to EaS while understanding the needs, perspectives, insights, and recommendations from NSBs. This survey is the basis for elaborating the questionnaire for the interviews with NSBs.

3. In-depth semi-structured interviews via videoconference with selected NSBs. The objective is to find best practices to foster EaS.

The results and analysis summarize the findings, investigate the perspectives and actions of ISO members and other key stakeholders regarding EaS, and suggest how to foster EaS at the national level.

5. Results and analysis

5.1 Data from phase 1: Interviews

5.1.1 Participants
The interviewees were divided into two groups: one with experts from international and regional SDOs, and another for professors/researchers. A total of 13 in-depth semi-structured interviews were conducted between June and October 2021. These lasted between 40 and 150 minutes each. After each consultation, an "interview note" was produced and sent to the interviewees for the correction of any factual errors.

Figure 2 – Regional Standards Organizations interviewed
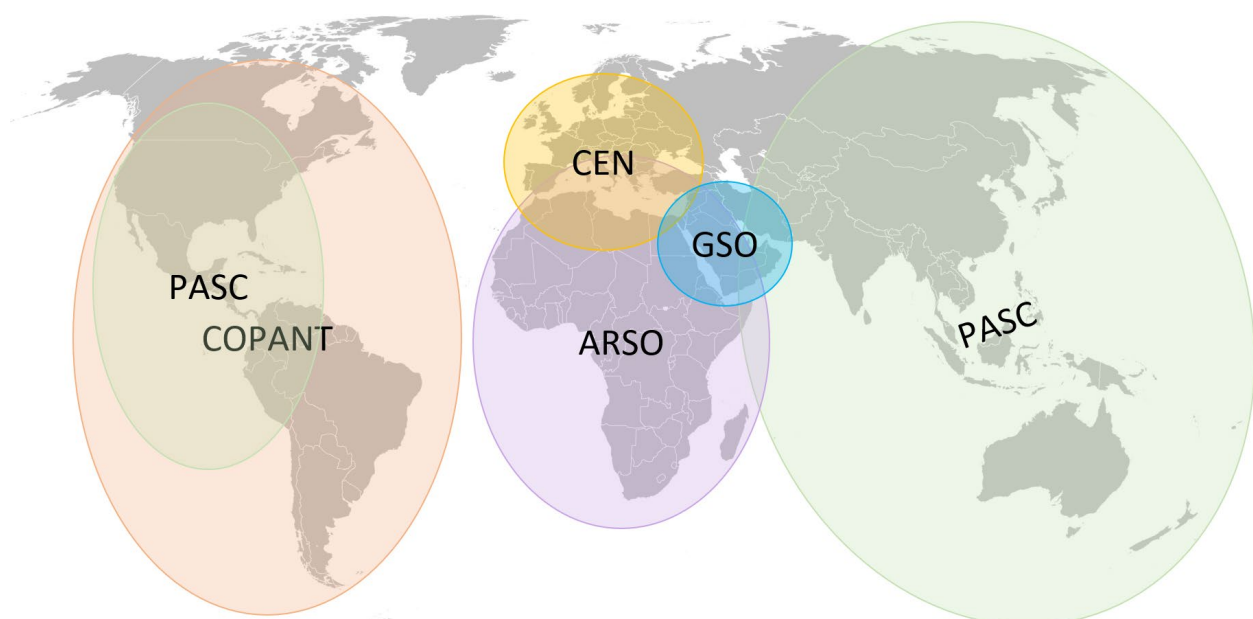
All (five) professors interviewed have been teaching at least one course related to EaS in the last year and have more than ten years of teaching experience in the topic of standardization. In

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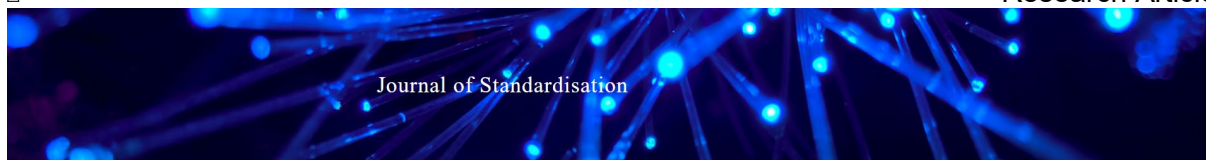
addition, three out of five have more than ten years of experience working in an NSB or international SDO.

Figure 2 shows the regional coverage of the (five) Regional SDOs interviewed, namely ARSO, CEN/CENELEC, COPANT, GSO, and PASC. In addition, experts from another three organizations were also interviewed: IEC, UNECE, and the International Federation of Standards Users (IFAN).

5.1.2 Approaches to EaS

The experts from international and regional SDOs believe that in EaS, the focus should be on a basic understanding of standards (awareness), including their application and benefits, and understanding how stakeholders can participate in the standardization process. The knowledge level varies according to the audience. For example, future experts should have the capability to distinguish, in the standardization process, the technical content from the policy content. Interviewees from developing regions emphasized that EaS should include the role of standardization in facilitating global trade.

On the other hand, the professors interviewed highlighted that it is crucial to differentiate the possible approaches to teaching standards, for example:

- Teaching about standards embedded in courses dealing with specific disciplines (e.g., Engineering, Business Management). This is how standards are taught today in most educational institutions.
- As dedicated lectures or courses about standardization that can be used in the context of different domains (e.g., standardization and innovation, standardization and the SDGs, etc.). Therefore, it can fit into several curricula.
- As a significant part of an academic curriculum, for example, modules or programs covering standardization issues in the relationship with other topics. (e.g., the Technopreneurship: Mastering smart ICT, standardization and digital trust for enabling next generation of ICT solutions).
- A specialized academic curriculum where standardization is one of the main topics.

The knowledge that the future experts should acquire and the adequate teaching approaches to EaS depend on the degree of expertise in standardization necessary for a given profession, local objectives and conditions. All approaches can add significant value to the students' formation.

5.1.3 EaS activities

When asked if their institutions had developed EaS activities in the last years, the SDOs group highlighted: webinars, boot camps, role-play gaming, the "classic" online and face-to-face materials (e.g., PowerPoint presentations), an online repository of materials, online training platforms, workshops, models of courses in standardization, and examples of educational models. Other less frequent activities from SDOs included awareness-raising among policymakers, the development of curricula for courses and Master's programs, online training, role-playing games, support for undergraduate projects, and essay competitions. These initiatives had policymakers, industries, NSBs, and universities as primary target groups. The outcomes of these activities and the materials developed were increased awareness from policymakers, increased involvement of NSBs and SDOs in teaching activities at universities,

and increased interest in EaS from industry and experts. Strategically, some regional SDOs said they are waiting for an initiative from ISO to follow and contribute more to the field.

All interviewees have developed teaching materials. However, not all materials produced by SDOs are helpful in universities (and vice-versa). For example:

> Most of the e-learning materials available (in standardization) produced by NSBs suffer from the same problem: too much effort in promoting formal standardization. This bias makes it useless for the best universities. Moreover, these materials should be more appropriate for Generation Z students (U-R05)[4].

Correspondingly, the literature underlines that the biggest challenge in teaching Generation Z students is to keep them actively involved and interested in the subject (Mijatovic, 2020; van de Kaa, 2020):

> Materials for Generation Z should be developed using appropriate pedagogical approaches, such as serious games, case studies, and links with the SDGs […]. The best teaching method to address this challenge (to keep the students actively involved in the subject) is learning by doing (U-R05).

> It is important to clearly show the link between standards and the subject addressed in an embedded course (U-R07).

Interviewees recommended linking students' existing interests (e.g., climate crisis) to standardization and clearly showing the link between standards and the subject addressed (in the case of an embedded course). The literature further highlights the importance of the type of content in EaS. The content should be engaging/appealing, starting with the global picture on a given subject, including practical applications of standards with which the students are familiar, and based on the real-world context with an understanding that people, processes, and organizations do not always work as expected (Fomin, 2020; Mijatovic, 2020). Pedagogical approaches may include in-class problem-based learning; in-class active learning (e.g., students participate in class); collaborative learning (e.g., there are interactions between classmates); inter-and transdisciplinary learning (e.g., integrating tools and concepts from more than one discipline to tackle complex standardization issues); case studies; discussion-based learning (e.g., the use of discussion to foment the understanding of issues, cases, ideas, etc.); writing-intensive learning; and serious games. This confirms findings in the literature (Aydan et al., 2017; H. J. de Vries, 2020a; Mijatovic, 2020).

Interviews reveal that the interaction between international and regional SDOs and universities is done through the NSBs, intermediating the activities and partnerships. The most common way is through guest lectures by NSB employees. On the professors' side, although some of them had previous experience working in SDOs, these interviewees were currently not involved in standards development. This is different for the Belgian professor Van den Bossche (2020) – he participates in standards development and involves his students: learning by doing.

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[4] Respondents can be either from a university (U) or SDO (S) and were enumerated chronologically after each interview. In the case of U-R05, he was the 5th interviewee from a university.

5.1.4 Challenges

At universities, education is linked to research:

> The subjects we teach and the research we do are prioritized according to their relevance to the academic community. Therefore, it is possible to foster education about standardization by fostering research on standardization (U-R05).

The interviewees' current challenges in EaS indicate the need to better support professors' activities through research, advertisement, and increasing awareness about the subject's importance.

> Who needs to take the initiative? Most stakeholders have a reason not to do it. The NSBs are the ones who should take the initiative. In this context, ISO has a strategic role. It should help its members stimulate EaS in their country (U-R05).

5.1.5 Coordination and cooperation

After the reflective exercise on challenges and strategies to foster EaS, the interviewees were asked which actions could be done per institution. The interviewees from regional and international SDOs believe that NSBs could:

- take the lead in developing a national EaS strategy;
- provide teaching;
- provide teaching materials;
- support universities, including participation in research;
- make standards more accessible to students;
- allow students to join standardization meetings;
- conclude cooperation agreements with universities to foster the development of standardization as an academic discipline.

NSBs could cooperate with other NSBs and SDOs. An NSB may play a coordinating and stimulating role by reaching out to ministries of education and other stakeholders such as consultants. Interviewees suggested that it is good practice to regularly share about EaS activities on social media.

5.1.6 Next steps

The interviewees started by highlighting the importance of building a more robust body of knowledge and increasing the number of academic publications, not only about the phenomenon of standardization but also about EaS. Indeed, the literature suggests that research and teaching have a strong relationship (van de Kaa, 2020). Therefore, fostering research would increase teaching activities in the field. One solution suggested would be bottom-up pressure from the labor market and the public in general to include EaS in curricula. The next set of suggestions centered around NSBs building relationships with education ministers and universities under a global strategy proposed by international SDOs, the idea being to raise awareness, build partnerships with these stakeholders, and gradually reach the students.

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In conclusion, the interviewees pointed out the inadequate number of initiatives in recent years and called for urgent action. They believe that at the national level, NSBs should take the lead, supported by SDOs at the global and regional levels. The latter might develop and follow strategies for EaS in order to ensure a systematic and coordinated approach to fostering EaS worldwide.

The assessment and mapping from phase 1, were the basis for elaborating the survey with NSBs. By means of this survey, we sought to further validate and explore these insights in NSBs all over the world, as described in the section below.

5.2 Data from phase 2: Survey

In order to map the activities, strategies, and perspectives of NSBs in Education about Standardization (EaS), a web-based survey was sent to all ISO members: 165 NSBs (one per country). The respondents were asked to reply considering the view of their institution. The survey was open from the 1st of September to the 27th of October 2021. The response rate was 55% (90 NSBs out of 165). Figure 3 displays the respondents' geographical distribution, and Table 1 shows the specific countries and regions.

Figure 3 – Respondents' geographical distribution
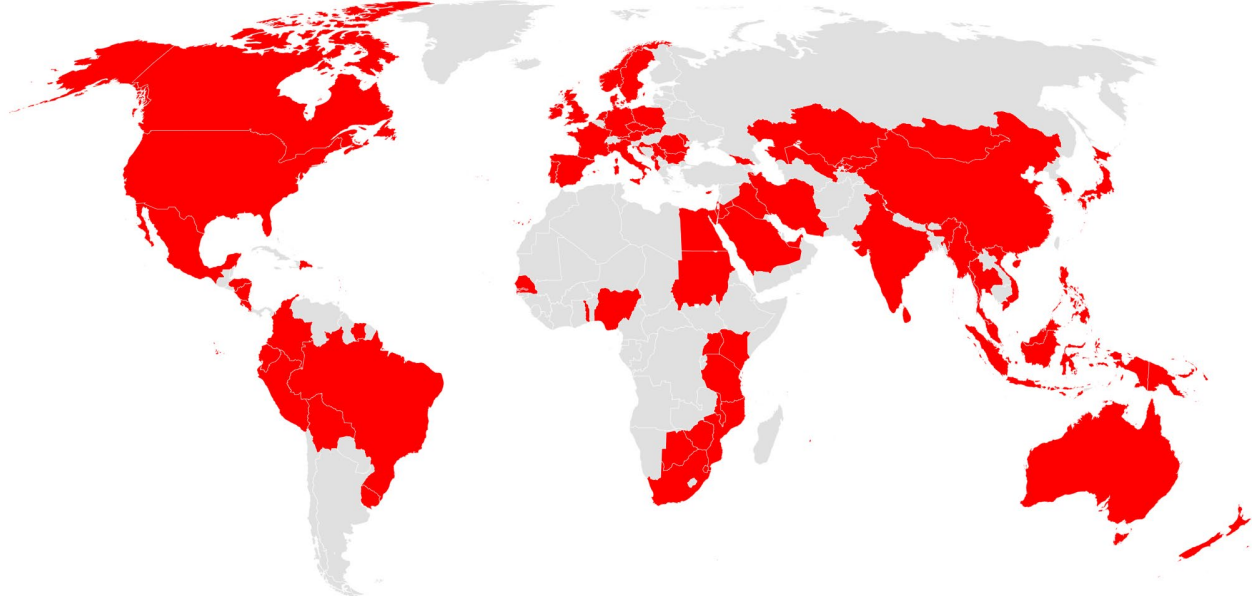
The respondents were composed mainly of NSB directors (44%), heads (17%), and managers and specialists (20%). A total of 89% replied that they had undertaken activities related to EaS in the last five years, such as the development of teaching materials and guest lectures at universities. The respondents revealed that 32% had up to 1 employee working full time on EaS activities, 19 between 1.1 and 5 employees, 18% did not have anyone, and 10% had 5.1 or more people working on EaS (Figure 4). When asked about which specific activities they had conducted, 64% organized public events, 62% teaching materials, 59% guest talks at universities, and 37% offered specific programs for young professionals. Other activities, 47%,

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Table 1 – Respondents' countries and regions

Region	Number of countries	Country list
Africa	17	Botswana; Egypt; Eswatini; Gambia; Kenya; Malawi; Mauritius; Mozambique; Nigeria; Senegal; Seychelles; South Africa; Sudan; Tanzania; Togo; Uganda; Zimbabwe
Americas	18	Barbados; Brazil; Canada; Colombia; Costa Rica; Dominica; Dominican Republic; Ecuador; Honduras; Mexico; Nicaragua; Peru; Bolivia; Saint Lucia; Saint Vincent and the Grenadines; Suriname; United States; Uruguay
Asia	27	Azerbaijan; Bahrain; Brunei Darussalam; China; Georgia; India; Indonesia; Iran; Iraq; Jordan; Israel; Japan; Kazakhstan; Kyrgyzstan; Malaysia; Mongolia; Myanmar; Palestine; Philippines; Republic of Korea; Saudi Arabia; Singapore; Sri Lanka; Thailand; United Arab Emirates; Uzbekistan; Viet Nam
Europe	25	Albania; Austria; Bulgaria; Croatia; Cyprus; Czechia; Denmark; France; Germany; Ireland; Italy; Luxembourg; Malta; Montenegro; Netherlands; Norway; Poland; Portugal; Moldova; Romania; Serbia; Slovakia; Spain; Sweden; United Kingdom
Oceania	3	Australia; New Zealand; Papua New Guinea
Total	90	

are composed mainly of participation in specific projects, workshops, and training programs.

Figure 4 – Full-time employees on EaS and activities conducted
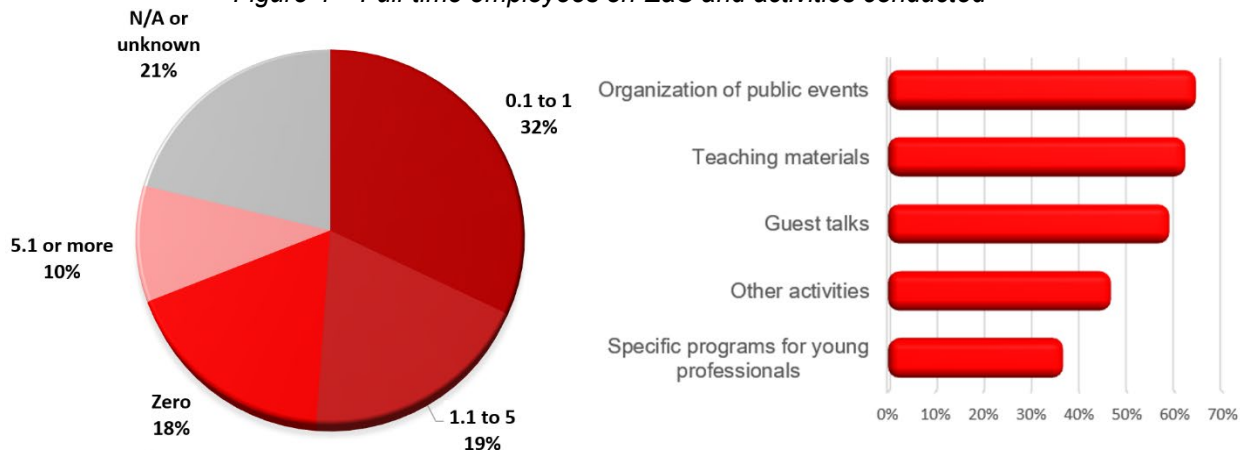
Whereas Figure 4 shows the main activities conducted, Figure 5 reveals the number of activities per region. Two conclusions that can be taken are that very few activities are being conducted in Oceania and Africa when compared with the other regions and that the activities are well diversified. There is no predominance of a specific activity or a specific region.

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Figure 5 – Activities conducted per region. Note: one country can have more than one activity.
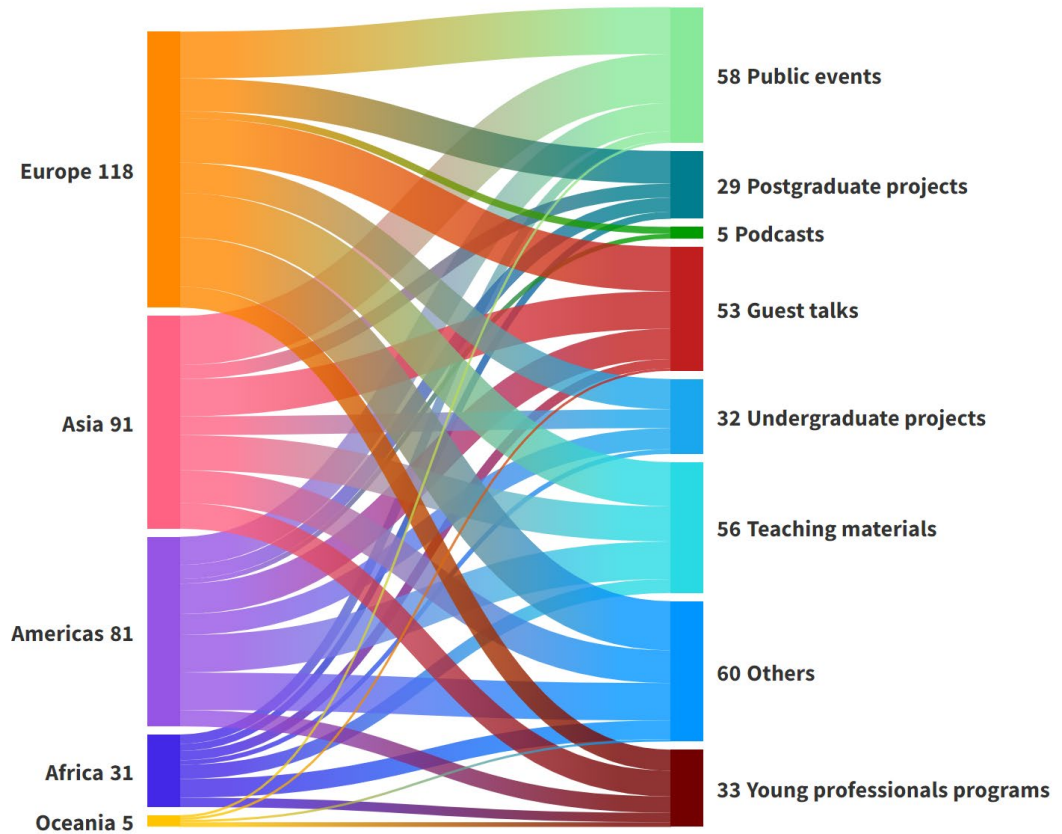

In addition, there are innovative activities conducted by a few countries that may serve as inspiration for other NSBs. Even though it is impossible to demonstrate the effectiveness of these pioneering activities' in the absence of empirical data, they may nevertheless represent excellent opportunities to develop EaS further. The actions in this category include the production of podcasts; offering students internship opportunities; participating in Curriculum Advisory Groups of higher education institutions; organization of national standardization Olympiads (for students from all educational levels); essay competitions; participation in radio programs; newsletters; preparing e-learning tools; simulations of technical committee meetings at the university in which students take the role of experts and practice consensus building to elaborate a mock standard; an escape-room on standardization; academic prizes; training for teachers at universities; organization of congresses; the nomination of standardization officers at universities to enhance the connection between professors, students, and the NSB; online serious games; half-day visits to the NSB's office; and offering reduced fees for students to purchase standards.

The respondents considered it extremely important that professionals understand standards and standardization. Figure 6 ranks the importance of awareness according to job function, starting with professionals working in standardization activities, quality management, laboratory scientists, engineers in R&I, policymakers, and production. This result agrees with the literature highlighting that EaS is important for professionals from these fields (e.g., IFAN 2018).

Nevertheless, the extent to which they should know about the topic varies according to their area – a phenomenon also observed in the literature (APEC, 2019; Blind & Drechsler, 2020; IFAN, 2018).

Figure 6 – Perceived importance of standardization awareness for specific stakeholder groups (according to NSBs). Mean in parenthesis. Descriptive statistics are available in the Appendices.
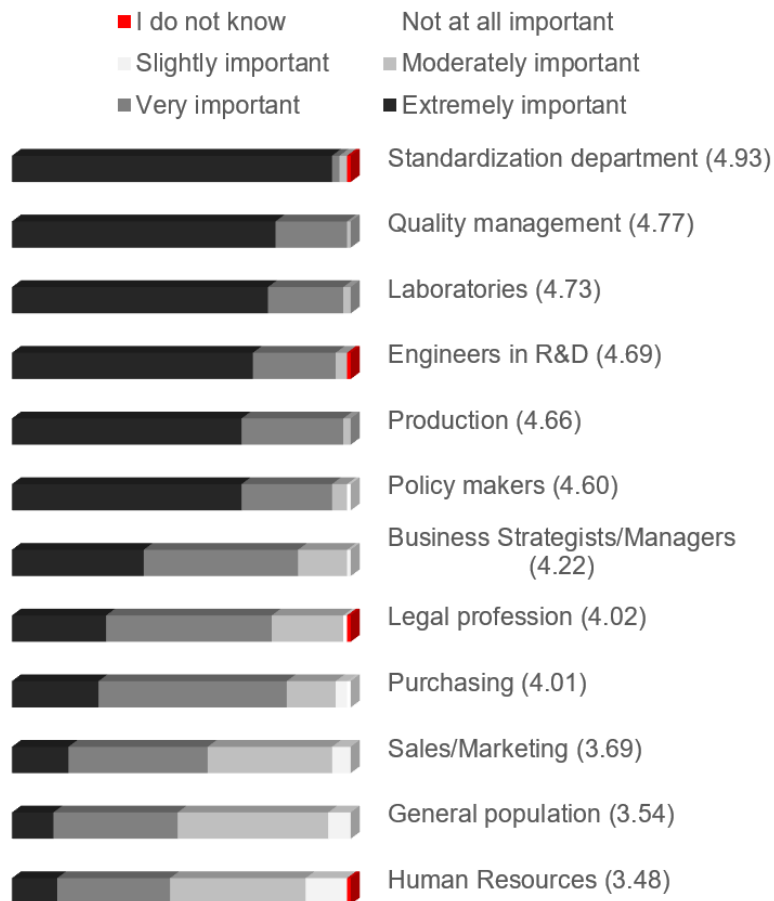
Regarding "who should do what" to foster EaS, respondents answered that NSBs should provide teaching materials and other resources to universities, engage with academic stakeholders, conduct guest lectures, invite students to observe standards-related activities (e.g., work of Technical Committees), allow student visits to their offices, and organize public events. International and regional SDOs should provide teaching materials, organize public events, conduct research on teaching approaches and topics, and develop programs for young professionals. Universities should conduct research on teaching approaches and topics, promote student participation in internship projects and offer support to undergraduate and postgraduate projects. Table 2 is further elaborated in the Discussion section.

Table 2 – Proposed actions per institution (according to NSBs)

Proposed action	NSBs[5]	Int./Reg. SDOs	Universities
Conduct research on teaching approaches and topics	69%	72%	80%
Provide teaching materials and other resources	90%	74%	59%
Engage with academic stakeholders to encourage the inclusion of EaS in their programs	91%	52%	54%
Conduct guest lectures	90%	51%	56%
Invite students to observe standards-related activities	93%	40%	56%
Allow and promote visits of students to NSB offices	91%	22%	64%
Promote student participation in internship projects	82%	43%	79%
Support postgraduate projects	83%	49%	78%
Support undergraduate projects	86%	37%	76%
Organize public events (e.g., Webinars)	93%	76%	62%
Host and promote podcasts	76%	68%	49%
Develop specific programs for young professionals	76%	76%	56%
Provide standards to universities for free or for a reduced fee	89%	54%	18%

5.3 Data from phase 3: National Standards Bodies expressing best practices to foster EaS

Phase 3 sought to explore further the answers provided in Phase 2 and investigate best practices. However, it is not easy to assess what is 'best' because situations differ, there is no EaS maturity model to evaluate the degree of a country's EaS development, and it was not in the scope of our study to develop such a model. Instead, we selected a set of simple criteria to help us select which countries had the most expertise on EaS and should be invited for an interview in Phase 3. NSB's participation in Technical Committees in ISO; participation in the survey; the number of FTEs in EaS; the number of EaS activities developed in the last five years; geographical location; and research on EaS topics. Asian countries score better on these criteria when compared to the other regions. The countries interviewed were Bolivia (IBNORCA), China (SAC), Colombia (ICONTEC), France (AFNOR), Germany (DIN), India (BIS), Japan (JISC), Saudi Arabia (SASO), South Africa (SABS), and the United Kingdom (BSI).

The interviewees were asked what they believe to be the best practices to foster EaS in their national context. In addition, they were asked to evaluate the set of actions proposed in the literature and in phases 1 and 2, and comment on whether those actions would help foster EaS in their national contexts. There was general agreement across the NSBs interviewed on the majority of suggestions to foster EaS in practice. The highlights were:

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[5] NSBs = National Standards Bodies OR SDOs at the national level.

- Research is needed to give evidence of the importance of standardization. High impact on business and society underpins the need to address it in academic curricula.
- Teaching materials: The idea of a global repository of teaching materials was very well received.
  - However, it is not clear who should execute it. NSBs argue that they do not have enough resources, and international and regional SDOs face language constraints since they would have to translate the materials into several languages.
  - Solutions proposed are based on cooperation, in which SDOs at the international level could maintain the online platform while NSBs upload and update teaching materials.
- Research Network: NSBs and professors could be organized in an online forum to exchange experiences, materials, case studies, etc. However, a small number of members per country (three to five) would be preferable to foster active participation.
- Maturity model: The development of a methodology to access a country's EaS development level and understand the challenges and opportunities to integrate EaS in different education systems would be helpful for NSBs. NSBs with divergent levels could work in partnerships for capacity building in education.
- Public events: A conference could help stakeholders to share information and network. Key points to be decided are the target group (professors, NSBs, or both); physical, virtual, or hybrid format; coordination (one centralized organization, regional organizations, a committee, etc.).
- A formal education strategy: Only the Asian interviewees had specific – and updated – strategies for developing EaS in their national contexts. Developing a formal strategy with clear goals and outcomes was considered by interviewees to be a key action for fostering EaS. This would also support the other key requirement for NSBs, which is to allocate budget and personnel specifically to EaS.
- Partnerships with educational institutions: MoUs (Memorandum of Understanding) and other forms of cooperation are helpful in making standardization part of academic curricula.
- Standards should be cheaper for students. NSBs should implement a "student subscription" that lowers the prices of standards for students and professors. This point contrasts with arguments raised by data from Phase 1. Some professors argued that the reason for not using standards in their teaching is not their price but rather their complexity and, in some cases, high abstraction.
- Some interviewees asked for materials and case studies on standardization for professors but seemed unaware that such materials already exist and are freely available (e.g., AFNOR, n.d.; APEC, 2010; BSI, n.d.; Hesser, Feilzer, & de Vries 2010; Nizar et al., 2021) and in many languages (e.g., JSA, n.d.).

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NSBs were asked about best practices for NSBs to foster EaS in their national context. Of course, their recommendations may not be applicable worldwide due to differences in the educational systems and policies. They advised NSBs to:

- perform exploratory research to understand the needs of the educational institutions, industry, and government in their region before acting. Guiding questions include:
  - Why is there a deficit in EaS in my region?
  - How are undergraduate and graduate programs developed?
  - What is the demand for programs related to standardization?
  - Why should our universities include standardization in their curricula?
  - Would local industries benefit and be interested in entry-level professionals with standardization knowledge?
- have an EaS strategy or have EaS elements added to the NSB's organizational strategy. Elements of the strategy should be prioritized according to their potential impact at the national and international levels;
- organize awareness-raising activities and events at the national level such as webinars, workshops, and conferences;
- collaborate with international and regional SDOs and demand their active participation in EaS activities.

Academic elements:

- Support educational institutions in developing EaS (e.g., develop academic courses, curricula, specializations ("majors"), and research).
  - This should be present at all educational levels.
  - Networking and relationship-building with teachers are essential.
  - The link between standardization and key areas should be clear. These areas include facilitating trade, sustainable development and SDGs, and economic benefits. Preferably, professors should be involved in Technical Committees.
  - Doctoral programmes would benefit both teaching and research activities.
- Assist in the creation of post-graduation programs for standardization professionals.
- Provide direct support to teaching activities (e.g., guest talks, workshops, sharing educational materials, promoting essay competitions, etc.), making use of online tools to reach a broader audience.
- Provide direct support to research (e.g., scholarships, guidance in thesis and dissertations, share data, etc.) and encourage students to work on projects related to real issues.
- Provide courses and activities to teachers about the benefits of standardization.

Non-academic elements:

- Build a relationship with the Ministry of Education. The idea is to enhance mutual collaboration and support in EaS activities.

- Provide training for local standardization employees and public administration employees. The training should cover critical areas such as key tasks of local standardization work and information about standardization at the international level.
  - The NSB should also encourage these managers to participate in Technical Committees. Therefore, the courses can also include how to draft standardization documents.
  - Provide training focused on "young professionals" in standardization. These are professionals that have just started working in the field regardless of their age.

6. Discussion

6.1 NSBs active in stimulating EaS

Based on a survey among NSBs and two rounds of expert interviews, this study seeks to provide insights into practices of EaS, the role of NSBs in stimulating EaS, and their perspectives on EaS. Both the literature, the qualitative interviews, and the survey data confirm the need for EaS. This need is seen all over the world, no matter the size of the country or whether it is an industrialized country, a developing country, or a country in transition. Most NSBs have some activities in place to stimulate EaS (Appendix B, Table 8). Two of these can be compared with the findings collected in 2013 by de Vries et al. (2014). At that time, 31 out of 58 NSBs (53%) reported they provided guest talks at universities, versus now 53 out of 90 (58%), and 19 (33%) reported contributions in the form of teaching materials versus 56 out of 90 (62%) now. Their surveys were also sent by ISO – both the higher response rate and the increase in these activities suggest that NSBs have become more active in supporting EaS. In Russia and other countries from the former Soviet Union, from which we got little response, EaS is in place as well (Jachia & Xu, 2012), leaving only most countries in the western part of Africa as a blank spot on the map of EaS. However, these activities do not mean that the mission has been accomplished, our interviewees and respondents perceive a huge gap between the need for better awareness and knowledge about standardization and what is offered in practice, despite the NSBs' very positive attitude and interest. For example, many NSBs have a low number of FTEs in EaS, have not developed many EaS activities, and are not aware of existing initiatives, such as the repository of teaching materials maintained by ISO (de Vries, Manders, and Veurink 2012 describe how they developed it). The question remains as to whether this discrepancy results from a bias in answering the EaS survey/interview questions or whether it is due to NSBs' financial and other resource limitations – for an NSB, EaS competes with many other priorities. NSBs have business plans to decide their priority areas for action. Thus, if they are to accord more importance to EaS, they must clearly understand the benefits this will bring them.

Below, we first reflect on the current gaps between the preferred and the current EaS situation and explore (best) practices to fill these gaps. These practices depend on the stakeholder's geographical location and culture. Finally, we discuss what NSBs can do to foster EaS in their country.

6.2 Potential solutions for filling the gap: what can NSBs do?

Our data suggest that NSBs are advised to:
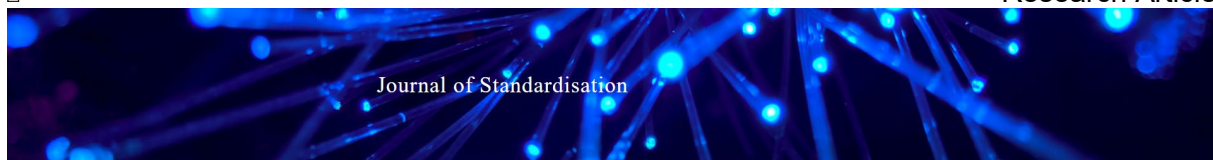
1. foster education through research, support to professors, and training activities;
2. foster exchange between standardization professionals and professors; NSB and government; NSB and universities; NSB and other SDOs;
3. divulgate the potential of standardization, its benefits and drawbacks to students and professionals;
4. determine clear objectives for the future by elaborating strategies tailored to the national education system.

Additional critical elements found in the literature (APEC, 2008; H. J. de Vries, 2014; Jachia et al., 2020) can be added to this list:

5. Stakeholders who have already stepped ahead and have been fostering EaS should continue and expand their actions.
6. Stakeholders should cooperate to build capacity by sharing their knowledge on best practices to foster EaS.
7. In the actions to foster EaS, give emphasis to new standards-related areas, such as sustainable development, gender equality, etc.

De Vries (2014), already described what can be done at the country level to stimulate EaS. Any party can take the lead in this, but the NSB is the most obvious one. Below we suggest practical ideas for how these actions could be executed based on the academic literature and interviewees' responses.

Based on our interviews, the survey and the literature (e.g., Choi & de Vries, 2013; Mijatovic, 2020; de Vries, 2014), we can conclude that NSBs should be involved in:

1. *Mapping and underpinning the needs for EaS*: foster exploratory research about standardization and EaS status at the national level and on EaS teaching strategies and topics;
2. *Fostering research and teaching*: develop relationships with universities and schools. At the university level, EaS can be stimulated in an indirect way by enabling research on standardization. A repository may provide teaching materials for professors and students in the national language (ISO, 2014; Puiu, 2020). Many other forms of cooperation between NSBs and universities may apply for the benefit of both (H. J. de Vries et al., 2014). The cooperation can be formalized by signing MoUs (Memorandum of Understanding), as is systematically done in Indonesia (Komala, 2012);
3. *Fostering exchange between stakeholders*: promote a network of people interested in the subject and build partnerships with and within institutions to enable experience and knowledge sharing while contributing to the further development of the field (H. J. de Vries et al., 2020). For example, creating or strengthening communities of practitioners at the national and international levels (e.g., de Vries, Trietsch, & Wiegmann, 2020); and creating and maintaining a network between researchers and professionals (e.g., ISO, 2014);
4. *Organizing public events*: to share the potential of standardization and raise awareness while strengthening the connection between standardization, research, and education. For example, organization of workshops with different target groups (students,

researchers, professors, professionals, policymakers, NSB, and SDOs); campaigns to promote the role of standards and to raise public awareness (e.g., Puiu, 2020); and promotion of national, regional, and international standardization competitions. NSBs should take a broad standardization perspective and avoid promoting themselves in any way, as this would undermine the academic spirit in the tradition of Humboldt's vision of education (Hesser, 2014);

5. *Creating strategies:* The NSB should elaborate a national strategy in cooperation with their government, industry and other stakeholders. A strategy should have clear goals and deliverables (e.g., APEC, 2009; de Vries, 2014). It is essential to understand key stakeholders before developing a strategy (see item 1). The strategic plan should include a roadmap for implementation. Such a plan may be inspired by the plans developed at the European level (CEN & CENELEC, 2011; CEN et al., 2012; Hesser & de Vries, 2011)

6. *Cooperating to build capacity*: A national steering group in which the main stakeholders are represented is the recommended way of mobilizing and committing the core stakeholders (Hesser & de Vries, 2011). Its secretariat (performed by the NSB) may help other institutions to build up expertise for teaching and to elaborate materials – again, avoiding self-promotion.

7. *Cooperating at the global and regional level*: Avoid re-inventing the wheel. Learn from other NSBs and SDOs. They also help in linking standardization and EaS to sustainable development, gender equality, etc. (Idowu et al., 2020).

Our research concludes that NSBs should take the initiative to foster EaS in a systematic way. This requires at least one FTE NSB staff responsible for EaS and an adequate budget for EaS activities. Further investigation is necessary to determine to which extent the industry should take part in fostering EaS. So far, they tend to show little commitment. We recommend in-depth interviews with business leaders in various industry sectors to investigate their perspectives and interests in EaS, considering they are the primary beneficiaries of and contributors to standards and standardization.

The three formal international SDOs, ISO, IEC, and ITU, have a crucial role in promoting and supporting EaS worldwide. They concentrate a vast network of members at the national level: either governments (ITU) or standards bodies (ISO and IEC) and have liaisons with other relevant organizations. Thus, their actions can be highly impactful, and relatively simple initiatives can significantly contribute to the further development of EaS. ISO and IEC can and do support their members at the national level.

6.3 The future of EaS

We have mentioned several current or past initiatives to foster EaS from actors such as EURAS, ICES, WSC, APEC, and national, regional, and international SDOs. However, the actual implementation of EaS has a long way to go. Many of the practices, ideas, and initiatives we found are not new – for example, some of these were already mentioned by de Vries and Egyedi (2007). Despite the accurate suggestions found in the literature, it is evident that EaS has not been sufficiently adopted worldwide. We consider that this failure is a result of multiple factors and challenges. As previously stated, we argue that, in order to successfully foster EaS worldwide, several initiatives must happen simultaneously, driven by a range of stakeholders.

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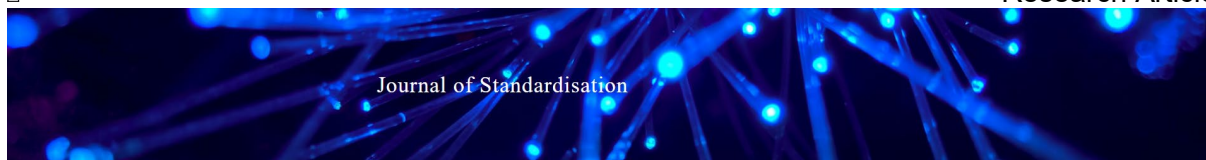
Therefore, if the correct strategy is applied by the relevant stakeholders, it will improve the EaS level worldwide, and this may trigger its professionalization and growth at the national level. Finally, it is necessary to develop standardization both as an academic discipline and a profession, for which research and education are needed and re-enforce each other. Therefore, academic initiatives such as the new *Journal of Standardisation* play a role as well by reporting about initiatives to foster EaS, publishing scientific studies on EaS, and being an outlet for standardization research as such.

6.4 Novelty

Whereas the results and suggestions of this paper might prompt a *déjà vu* feeling for some readers, given similar results found in the literature, our proposal is unique for various reasons. The 90-country dataset provides a global benchmark on real EaS activities (Appendix B, Table 8), the NSBs perspective on the importance of EaS (Figure 6), and actions they propose to foster EaS (Table 2). In addition, best practices are further explored in depth (section 5.3). This resulted in a comprehensive set of actions proposed for fostering EaS, particularly for NSBs. The solutions proposed in section 6.2, once single pieces of a larger puzzle, have now been slotted into place. For example, de Vries and Egyedi (2007) point out that more research is needed on the subject, such as national and regional strategies to foster EaS, which is one of the main objectives of this article. In addition, while they suggested that a strong national policy and cooperation between stakeholders are necessary to foster EaS, we expand these recommendations in depth and detail (section 6.2).

More recently, the book by Idowu et al. (2020) provides several suggestions for NSBs. In its 7th chapter, Puiu (2020) highlights the importance of creating strategies, organizing public events, partnerships between SDOs, national campaigns to promote standardization, etc. Once more, this work goes further by providing details and suggesting additional solutions to foster EaS.

Another highlight is the out-of-the-box ideas presented in section 5.2, which are almost absent from the literature. For example, the use of podcasts as a tool to foster EaS, simulation of a technical committee meeting at the university, escape-room on standardization, and the nomination of standardization officers. However, we underline that very few countries have adopted these, and further investigation into their effectiveness is needed.

6.5 Practical outcomes

The outcomes of this research served as an input for ISO to design its Education Programme, which aims to support ISO members in promoting EaS in their countries at all educational levels. It consists of six projects to be implemented in cooperation with ISO members over three years.

In the longer term, ISO hopes that fostering EaS will lead to increased societal awareness about the benefits of standards and the standardization system, in particular amongst younger people. This increased awareness will hopefully translate to more users of standards and new experts entering standards development.

In the shorter term, they hope that ISO members will benefit from the individual Programme projects:

- "EaS maturity model" will help members assess what stage they are at in terms of their work on EaS, and elaborate a strategy to meet their objectives;
- "EaS Network" will facilitate contact and the exchange of materials between researchers and NSBs;
- "EaS materials' repository" will provide members with an up-to-date set of materials and best practices, shared by other members and those in the EaS Network and organized, formatted, and translated by ISO;
- "EaS webinars and workshops", will showcase the work of ISO members and raise the awareness of different audiences about the importance of EaS;
- "EaS research projects" will recruit young students and researchers to ISO and NSBs by supporting students to develop academic work, for example, with financial awards and certificates;
- "EaS international joint conference" will foster exchanges between NSBs and the academic community while raising standards, standardization, and ISO visibility.

The programme is set to start in 2023.

6.6 Recommendations for future research

The field of standardization, in general, presents excellent opportunities for research development. In EaS, more specifically, we believe that the following contributions are of immediate need:

To systematically evaluate whether EaS dissemination, adoption, and development as a discipline have succeeded or failed over the last decades. For example, to compare EaS to other fields with common characteristics (e.g., patents, Education for Sustainable Development) to evaluate whether these other areas have had a higher adoption/expansion rate (in terms of number and quality of publications, adoption in the educational systems, financial investments, etc.).

To investigate, in case-study-based research, what enabled NSBs to engage in EaS activities and what prevented other NSBs from doing the same. In addition, to understand how relationships between NSBs and governments are established and what the key success factors are.

7. Conclusion

Standardization's importance is increasing, but many people in business and society lack awareness and knowledge. Therefore, EaS is crucial. Education is organized at the national level, and at that level, NSBs are the organizations fully devoted to standardization. Therefore, this paper seeks to investigate what NSBs are doing to stimulate EaS and to hear their perspectives. We do this by studying the literature, interviewing core experts in the field, making an inventory of NSB practices and suggestions, and tracing and analyzing best
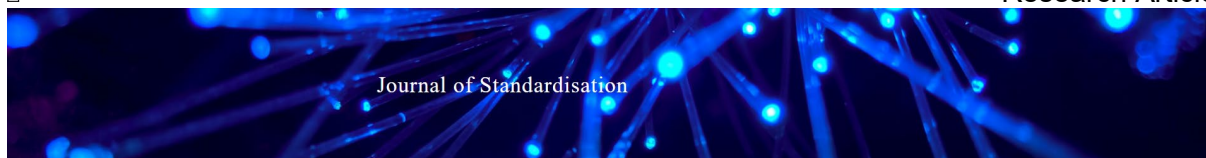
practices. It turns out that most NSBs all over the world have activities in this field, and findings suggest the number of activities is increasing. However, much more needs to be done. Based on the literature and our empirical findings, we come up with suggestions for NSBs to accelerate the implementation of EaS in their countries, to allow business and society to better reap the benefits that standardization provides.

The main limitation of this research is that, despite the high response rate (55%), our global survey probably has an overrepresentation of countries with better performance in EaS: these NSBs have the personnel to deal with EaS matters and could actively provide inputs to the survey and interviews. Another limitation is that we do not build an inventory of the EaS activities that are being done at the national level – although we gathered much information, we realize that this is still incomplete.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available due to privacy restrictions.

Author Contributor (CRediT): Conceptualization, L.C.G., H.J.V., B.C.; literature review, L.C.G., H.J.V.; methodology, L.C.G.; data collection L.C.G.; results and analysis, L.C.G., H.J.V.; discussion, H.J.V., L.C.G.; writing-original draft preparation, L.C.G.; writing-review and editing, L.C.G., H.J.V., B.C.

Conflicts of Interest: The authors declare no conflict of interest.

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Appendix A – Data Collection 1 – SDOs and professors – Interview questions

Questions for Standards Development Organizations

1) We understand that users and potential experts do not have enough knowledge about standards/standardization. What would you consider to be the priority topics on EaS that users and future experts should be better informed about in the next 10 years?
2) Have you either developed EaS activities (e.g. develop materials, give a group lecture, etc.) or contributed to them in the last 5 years?
   a. What were the activities and materials?
   b. What have been the outcomes of these activities?
   c. What are your organizational goals regarding EaS?
3) Which educational institutions (if any) do you work with on EaS?
4) Have you encountered any challenges in terms of your work on EaS or promoting EaS in your national context?
5) How do you think that EaS could be improved in the future?
6) What are your ideas for what your organization could do?
7) What do you think others* could do in future to improve EaS?
   a. ISO
   b. International and Regional SDOs
   c. NSBs
   d. Universities

Questions for researchers and experts

1) How have you taught students about standards in the last 5 years?
2) Which teaching methods do you think are most effective for EaS?
   a. Would you share some teaching materials and articles with us? (We plan to update our repository).
3) Are you involved in the standard development process? Do you teach about this process?
4) Which Standards Development Organizations (if any) do you work with on EaS? (collaboration with)
5) Have you encountered any challenges in your work on EaS?
6) Have you encountered any challenges with promoting EaS in your institution?
7) How do you think that EaS could be improved in the future?
8) What are your ideas for what educational institutions could do?
9) What do you think Standards Bodies should do in future to improve EaS?
10) In your opinion, what is the best thing ISO could do to help with EaS?
11) If you had limitless power/resources, what you would firstly do/change to advance EaS?

Summary tables

Tables 3, 4, 5, and 6 summarize the answers observed during the interview. They do not include specific details and commentaries due to privacy concerns.
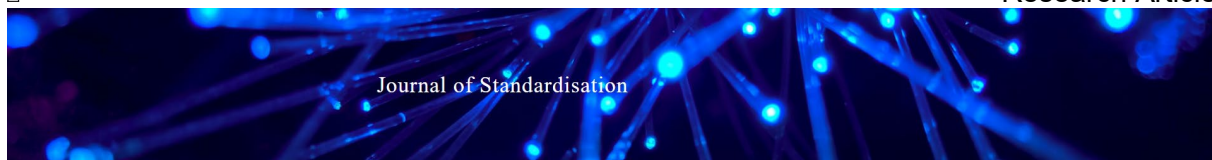
Table 3 – Activities developed

Activity/Respondent	Universities (N = 5)	SDOs*[6] (N = 8)
Support to postgraduate projects	-	4
Teaching materials (e.g., slides, publications)	5	6
Organization of public events (e.g., webinars, workshops)	-	7
Workshops (restricted to students from their courses)	2	-
Guest talks	5	1
Other activities	4	6

Table 4 – EaS challenges

Challenge/Respondent ID*	Universities (N = 5)	SDOs* (N = 8)
Lack of a strategy to foster EaS (SDOs and NSBs)	-	4
Lack of collaboration among stakeholders (universities, SDOs, and NSBs)	1	-
Lack of awareness (policymakers/education ministers)	-	4
SDOs and NSBs do not have enough awareness about EaS' importance	1	2
Universities do not have enough awareness about EaS' importance	1	-
Students do not have enough awareness about standards' importance	3	-
Make EaS attractive to students (incl. Adequate materials)	3	1
Lack of support from universities	3	-
Lack of support from SDOs and NSBs	2	1
Understand how standards work in practice (for students)	1	-
Lack of professors and researchers in the field	1	-
Lack of experts in the field	1	2
Lack of research on EaS	1	-
Lack of financial resources	-	2

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[6] SDOs* = Regional SDOs, IEC, UNECE, and IFAN

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Table 5 – Opportunities to promote EaS

Opportunity/Respondent ID*	Universities (N = 5)	SDOs* (N = 8)
Developing extracurricular activities	1	1
Raise policy makers' awareness (to acquire more support from them)	1	2
Raise companies' awareness	1	-
Raise universities' awareness	1	2
Raise students' awareness	1	3
Increase the cooperation among institutions	1	1
Invest in online teaching	1	3
Develop a strategic approach to EaS (NSBs and SDOs)	3	1
Development of EaS materials for Generation Z, Alpha	1	2
Promote the involvement of researchers in standardization activities, and experts in teaching activities	2	2
Identify and monitor EaS key performance indicators	-	1

Table 6 – Proposed actions per institution (according to Professors and SDOs, N=13)

Proposed action/Institution	Universities	NSBs*[7]	SDOs**[8]
Conduct research on teaching approaches and topics	3	2	1
Provide teaching materials and other resources	1	3	5
Provide teaching	2	1	
Engage with academic stakeholders to encourage the inclusion of EaS in their programs		6	3
Support postgraduate projects	3	2	1
Provide formation to professors	1		1
Support undergraduate projects	3	2	
Organize public events (e.g., Webinars, Workshops)	1	1	3
Develop specific programs for young professionals	1		1
Provide standards to universities for free or for a reduced fee		1	1
Foster more cooperation among SDOs and NSBs.		1	4
Promote EaS to policymakers	1	3	2
Promote EaS among NSBs (awareness raising)		4	3
Promote EaS to the industry		1	1
Create a formal EaS implementation and development strategy		2	5
Other actions	2	2	4

Appendix B – Data Collection 2 – NSBs – Survey questions

Questions for NSBs

1) Respondent's contact details (full name, position, department/team, organization, email).
2) In the last 5 years, has your organization conducted activities related to Education about Standards? For example, developed teaching materials, provided guest lecturers on standards at universities, etc. (yes/no)
3) Please specify which activities you have conducted.
4) Which educational institutions (if any) have you collaborated with on Education about Standards?
5) How many people in your standards body work full time on education about standards? (If someone works for half of their time on EAS, this would 0.5, for example).
6) In your opinion, how important is it that the following groups have a good understanding of standards and standardization?

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[7] NSBs* = National Standards Bodies OR SDOs at the national level.

[8] SDOs** = Regional and International SDOs

7) In your opinion, what could be done by the following institutions to foster Education about Standards? (International and Regional Standard Development Organizations; National Standard Bodies (NSBs); Universities)

8) If you have any other suggestions, observations or comments about EaS, please share them here.

Summary table

Table 7 displays the descriptive statistics from "Figure 6 – Perceived importance of standardization awareness for specific stakeholder groups (according to NSBs). Mean in parenthesis. Descriptive statistics are available in the Appendices.

Table 7 – Descriptive statistics: Survey with NSBs

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Q6.1. Policy makers	90	0	4.60	0.07	0.68	1	4	5	5
Q6.2. Legal profession	89	1	4.03	0.08	0.78	1	4	4	5
Q6.3. General population	90	0	3.54	0.08	0.80	2	3	3	4
Q6.4. Engineers in R&D	89	1	4.69	0.06	0.54	3	4	5	5
Q6.5. Sales/Marketing	90	0	3.69	0.09	0.82	2	3	4	4
Q6.6. Business Strategists/Managers	90	0	4.22	0.08	0.73	2	4	4	5
Q6.7. Standardization department	89	1	4.93	0.04	0.33	3	5	5	5
Q6.8. Quality management	90	0	4.77	0.05	0.45	3	5	5	5
Q6.9. Production	90	0	4.66	0.06	0.52	3	4	5	5
Q6.10. Purchasing	90	0	4.01	0.08	0.80	1	4	4	5
Q6.11. Laboratories	90	0	4.73	0.05	0.49	3	4.75	5	5
Q6.12. Human Resources	89	1	3.48	0.09	0.88	2	3	3	4

N = number of respondents; N = number of respondents who answered "I do not know"*

Table 8 – Activities conducted by NSBs

Activity	Yes	No	I do not know	Percentage (yes)
Podcasts	5	84	1	5.6%
Support to postgraduate projects	29	56	5	32.2%
Support to undergraduate projects	32	52	6	35.6%
Specific programs for young professionals	33	54	3	36.7%
Other activities (specify)	42	N/A	N/A	46.7%
Guest talks	53	34	3	58.9%
Teaching materials	56	31	3	62.2%
Organization of public events	58	30	2	64.4%

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Appendix C – Data Collection 3 – NSBs – Interview questions

1) Please, provide clarifications on the answers provided in Data Collection 2.
2) Provide feedback on the proposed actions to foster EaS (sent in advance to the NSB via email).
    a. EaS materials' repository
    b. EaS Network
    c. EaS maturity model
    d. EaS webinars and workshops
    e. EaS research projects
    f. EaS international joint conference
    g. EaS regional programs
3) In your view, what are the best practices to foster EaS in your national context? How to make them happen?