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**UNIVERSITÉ
DE GENÈVE**

**GENEVA SCHOOL
OF SOCIAL SCIENCES**
Department of Sociology

SUPPORTING NATIONAL STANDARDS BODIES TO STIMULATE EDUCATION ABOUT STANDARDIZATION

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Master Thesis

Submitted in fulfillment of the requirements of the degree of Master of
Standardization, Social Regulation and Sustainable Development

**Under the supervision of Professor Marlyne Sahakian,
and the co-supervision of Professor Henk de Vries**

April 2022

University of Geneva – Department of Sociology
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I would like to cite Matthew 7:7–8:

⁷Ask and it will be given to you; seek and you will find; knock, and the door will be opened to you. ⁸For everyone who asks receives; the one who seeks finds; and to the one who knocks, the door will be opened.

TABLE OF CONTENTS

LIST OF FIGURES	7
LIST OF TABLES	8
ABSTRACT	9
1. INTRODUCTION	10
2. ISO: HISTORY, VISION AND GOALS	12
3. RESEARCH & INNOVATION UNIT: EDUCATION	13
3.1 AUTHORSHIP PER DELIVERABLE	14
4. LITERATURE REVIEW	15
4.1 INITIATIVES ON EAS	17
5. METHODOLOGY AND CONCRETE TASKS	20
5.1 PROJECT PHASES	20
6. RESULTS AND ANALYSIS	22
6.1 DATA FROM PHASE 1: INTERVIEWS	22
6.1.1 Approaches to EaS	22
6.1.2 EaS activities	23
6.1.3 Challenges	24
6.1.4 Coordination and cooperation	25
6.1.5 Next steps	26
6.2 DATA FROM PHASE 2: SURVEY	27
6.3 DATA FROM PHASE 3: NATIONAL STANDARDS BODIES EXPRESSING BEST PRACTICES TO FOSTER EAS	31
6.4 DISCUSSION	34
6.4.1 Need for EaS	34
6.4.2 What should be achieved (What we would like to achieve?)	34
6.4.3 Potential solutions for filling the gap	34
6.4.4 Operationalizing the solutions (concrete actions)	35
6.4.5 The role of stakeholders on EaS at the different levels	37
6.4.6 The future of EaS	38
7. CONCLUSION	39
REFERENCES	40
APPENDICES	44
APPENDIX A – DATA COLLECTION 1 – SDOs AND PROFESSORS – INTERVIEW QUESTIONS	44
APPENDIX B – DATA COLLECTION 2 – NSBs – SURVEY QUESTIONS	48
APPENDIX C – DATA COLLECTION 3 – NSBs – INTERVIEW QUESTIONS	50
APPENDIX D: ISO EDUCATION STRATEGY PROPOSAL	51
ISO EDUCATION STRATEGY	52

LIST OF FIGURES

Figure 1 – Methodological framework	20
Figure 2 – Regional Standards Organizations interviewed	22
Figure 3 – Respondents’ geographical distribution	27
Figure 4 – Full-time employees on EaS and activities conducted	28
Figure 5 – Perceived importance of standardization awareness for specific stakeholder groups (according to NSBs). Mean in parenthesis. Descriptive statistics are available in the Appendices.	29
Figure 6 – Actions suggested for ISO	30

LIST OF TABLES

Table 1 – Respondents’ countries and regions	27
Table 2 – Proposed actions per institution (according to NSBs)	29
Table 3 – Activities developed.....	45
Table 4 – EaS challenges	45
Table 5 – Opportunities to promote EaS	45
Table 6 – Proposed actions per institution (according to Professors and SDOs, N=13)	46
Table 7 – Descriptive statistics: Survey with NSBs	48

ABSTRACT

Abstract: **[Problematic]** Standardization can be an important component for sustainability in business and society. However, many people are unaware of how the standardization system works and of its benefits. Although there has been research done on this subject for several decades, it is unclear to which extent the insights proposed thus far have contributed to increasing or improving education about standardization worldwide. **[Purpose]** The purpose of the project developed in the internship is to propose a new Education Strategy for ISO. This strategy outlines how ISO can best support its members to promote Education about Standardization (EaS) at all educational levels. The secondary objectives are (1) to provide insights into how standards are being taught at educational institutions around the world, (2) to understand the challenges and opportunities related to integrating standards into curricula, and (3) to investigate the perspectives and actions of ISO members and other key stakeholders with regard to EaS. This project also supports Goal 1 of the ISO Strategy 2030, “ISO standards used everywhere”, priority 1.1 “demonstrate the benefits of standards” and Goal 3, ‘all voices heard’, priority 3.2, “advance inclusivity and diversity in the ISO system”. **[Methodology]** The data are collected in three steps: in-depth interviews with university professors and regional SDOs; a survey with national standards bodies (NSBs); and in-depth interviews with NSB experts. **[Findings]** The results clarify the need for EaS, what should be achieved in the field in the following years, potential solutions to reach the objectives and how to operationalize them, the role of key stakeholders, and the future of EaS. **[Practical implications]** This article advances knowledge in the field of EaS, with a focus on the role and actions of SDOs. This work also provides suggestions on how stakeholders can work together to foster EaS. **[Originality/value]** This is one of the first studies to investigate how international standards are represented in higher education, and to focus on providing strategies for EaS worldwide.

Keywords: Education about Standardization, Standards Development Organizations, 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 (Idowu et al. 2020). Along with this expansion in the field, many stakeholders, including governments and industry experts, know little about standards and standardization at strategic, tactical, and operational levels (European Commission 2022; de Vries 2020b). 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). This lack of awareness identified in the literature establishes the starting point of this research.

EaS has the potential to provide students with the skills and knowledge to use international standards as soon as they enter the workforce, which could, in turn, foster increased trade and competitiveness in the global market. Many researchers therefore argue that it is necessary to raise awareness about how standards and the standardization system work (Jachia, Kouzmine, and Xu 2020; Kanevskaia 2020; Katusic et al. 2017; Puiu 2020). In addition, Standards Development Organizations (SDOs) have indicated the need for fostering Education about Standardization (EaS) due to the difficulty of finding technical experts for standards development work (European Commission 2022). Despite the existence of some initiatives in education – at schools, universities and in post-formal education and training (see, for example, Curtis et al. 2021; Jachia et al. 2020; de Vries, Trietsch, and Wiegmann 2020), it is still widely recognized that the actions taken so far are not sufficient and more should be done to integrate standards and standardization into education (European Commission 2022; Jachia et al. 2020; Kanevskaia 2020).

Standardization can offer direct benefits to society by fostering economic and sustainable development. In the economic field, they can facilitate trade (Potoski and Prakash 2009) and contribute to promoting economic development in some instances (Blind, Ramel, and Rochell 2021). Yet, economists have systematically neglected the role of standardization in economic growth (Heikkilä, Ali-Vehmas, and Rissanen 2021). In terms of sustainable development, recent research shows that even though most standards were initially not designed for addressing the SDGs (Sustainable Development Goals), the Agenda 2030 (UN 2015) objectives, they still can substantially help to achieve them (e.g., Gueorguiev and Kostadinova 2021; Ikram et al. 2021; Serhan and Nahon 2021; Walshe et al. 2020). A practical example of SDG 3 (Good Health and Well-being) is how standards helped to mitigate the COVID-19 crisis while promoting innovation (de Vries 2021). However, some authors argue that some aspects of the standardization system would have to be modified for real or higher impact on the climate agenda (Blind and Heb 2021; Zhao, Castka, and Searcy 2020). Therefore, standards can contribute to economic and sustainable development, and so does the EaS.

The book entitled “Sustainable Development: Knowledge and Education About Standardisation” (Idowu et al. 2020) provides state of art on the topic and highlights its importance for sustainable development. The first chapter highlights the importance of EaS in underscoring the prominent role of standards in policy and business and the importance that students have enough knowledge and skills to “understand the complex issues of sustainable development, and the role of standards in addressing them” (Wright et al. 2020, p. 12). In addition, sustainability can be directly addressed by EaS (de Vries 2020a). EaS provides

the tools for the students to produce and work straight out of the university aligned with international standards, as a short path for fostering trade and competitiveness in the global market. Despite its benefits, a significant knowledge deficit on standardization was identified among students and people in general (e.g., Kanevskaia 2020; Puiu 2020; Vasileva 2020). Thus, the current EaS state is unable to match market and regulatory demands (Jachia et al. 2020).

The lack of awareness about the importance of standards could potentially impact the future use of standards to address societal issues and the availability of future experts to participate in the standards development process. This work builds on the existing literature on EaS and the perspectives of critical stakeholders to suggest new education strategies for SDOs. These strategies will outline how SDOs can best support other stakeholders to promote EaS at all formal educational levels (primary, secondary, and pre-qualification levels), post-qualification education, and increase young people's awareness about standards' benefits and how the international standardization system works. Therefore, the systematic lack of awareness identified in the literature establishes the starting point of this research.

This research aims to (1) provide insights into how standards are being taught at educational institutions around the world, (2) understand the challenges and opportunities of integrating standards into curricula, (3) and investigate the perspectives and actions that National Standards Bodies (NSBs) have been taken in Education about Standardization (EaS), in order to propose strategies to foster EaS at all educational levels in national and global contexts.

2. ISO: HISTORY, VISION AND GOALS

The International Organization for Standardization (ISO) was founded in 1947 through the merger of two organizations, the International Federation of the National Standardizing Associations (ISA) and the United Nations Standards Coordinating Committee (UNSCC). Nowadays, ISO has three official languages (English, French and Russian) and has 165 members. Member bodies are Standards Development Organizations (SDOs) that perform activities at the national level. Each country can have only one institution recognized as an ISO member. Usually, this institution is part of the government. ISO's main deliverables are the International Standards (further defined in the Literature Review section).

The ISO Strategy 2030 (ISO 2021) defines ISO's vision (why ISO does what it does), the mission (what ISO does and how it does), the goals (what ISO needs to achieve to realize its mission and vision), and priorities (where ISO needs to focus its resources to accomplish its objectives). The ISO Strategy 2030 is aligned with the Agenda 2030 (UN 2015), and it aims to “make the lives easier, safer and better” by “providing a neutral platform where experts over the world come together to agree on standards” (ISO, 2021 p. 10), and fulfilling the goals for “ISO standards used everywhere”, “meeting global needs”, and “all voices heard” (ISO, 2021 p. 13).

On the international scale, ISO has clear priorities that relate to EaS. The 2021 publication of the ISO Strategy 2030 and the London Declaration represent the organization's commitment to climate change and promote International Standards as an enabler and accelerator of solutions towards the SDGs. In addition, the ISO Strategy 2030 set three goals and six priorities which represent where ISO needs to focus its resources to realize its mission and vision. In order to achieve the goals, “ISO standards used everywhere”, “meeting global needs”, and “all voices heard”, people need to be aware of what standards are and how the standardization system works. Therefore, EaS is essential for awareness-raising and ensuring that young people today will become the standards users and makers in the future.

3. RESEARCH & INNOVATION UNIT: EDUCATION

Until 2017, ISO carried out activities related to education and research through the ISO Academy. The activities were mainly related to the Action Plan for Developing Countries and included promoting cooperation between NSBs and educational institutions, ISO and universities (e.g., UNIGE), workshops, a brochure about good practices for collaboration of NSBs and universities, the ISO Award for Higher Education (to promote higher education institutions running successful programs about standardization), and created a repository of teaching materials. After the end of the ISO Academy, in 2020, education was added in the mandate of the ISO/CS Research and Innovation unit (R&I). The unit is responsible for research activities, mainly focused on the benefits of the standards and, more recently, sustainable development; innovation activities related to identifying future opportunities for standardization (foresight); and promoting Education about Standardization. The unit identified that people in general do not have enough awareness about standards and standardization. Once this issue was identified, a scoping exercise was performed¹, and in April 2022, we started this research to develop a new Education Strategy for ISO. This strategy outlines how ISO can best support its members to promote Education about Standardization (EaS)² at all educational levels.

The main deliverables of this project are compiled in a report delivered to the R&I unit, composed of an open-access academic article and the ISO Education Strategy, which is based on the article's findings. Secondary deliverables are the materials shared and data collected in phase 1 (interviews with professors and regional Standards Development Organizations (SDOs)), phase 2 (online survey with National Standards Bodies (NSBs)), phase 3 (interviews with NSBs) and **this** Master Thesis for the Masters of Arts in Standardization, Social Regulation, and Sustainable development at the University of Geneva. This Master thesis has, therefore, elements from the report, article, and strategy. The full report and strategy are confidential. Other deliverables are MS Excel files of contact lists of stakeholders involved in EaS and EaS representants from 90 ISO members and PowerPoint presentations.

This project exists alongside many other initiatives that, together, aim to raise awareness about the benefits of standards/standardization and increase inclusivity and diversity in the ISO system. All work undertaken in the context of this project must take into consideration the broader environment and other projects related to, for example, attracting the next generation/young professionals to standardization, the ISO Digital learning platform and the ISO Next Generation Award.

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¹ The “Education workshop 2020” took place virtually on the 8th of April 2020, led by the R&I unit. A group of ten stakeholders, including professors, specialists in standardization, ISO/CS employees, and NSBs employees, participated in the exercise. This activity also highlighted the interest of the ISO community in the further development of awareness-raising actions for young people.

² Education about Standardization (EaS) is about providing the knowledge and information necessary for someone to be aware of what standards are, how the standardization system works, understand the benefits and drawbacks that standards bring to society. EaS should also contribute to transforming this awareness into specific actions.

3.1 AUTHORSHIP PER DELIVERABLE

The report was elaborated by Lucas Catalani Gabriel (L.C.G.) with the active collaboration of Belinda Cleeland (B.C.), Head of Research and Innovation in ISO/CS and Henk J. de Vries (H.J.V.), Professor at the Rotterdam School of Management, Erasmus University (RSM). The initial scope had contributions from Erica Potts (E.P), Programme Manager in ISO/CS. The Master Thesis was reviewed by Professor Marlyne Sahakian.

More specifically:

Report and article: Conceptualization, L.C.G., B.C., E.P.; literature review, L.C.G.; methodology, L.C.G.; data collection L.C.G.; results and analysis, L.C.G.; discussion, L.C.G.; supervision. H.J.V., B.C., E.P.; writing-original draft preparation, L.C.G.; writing-review and editing, L.C.G., H.J.V., B.C.; supervision, H.J.V., B.C.

ISO Education Strategy: L.C.G., with constructive feedback provided by H.J.V.

Master Thesis: Based on the report and article with supervision and constructive feedback provided by H.J.V. and M.S.

4. LITERATURE REVIEW

The multi-disciplinary field of EaS has been evolving in the last decades. As a result of the changes, complexity, and variety of topics related to the theme in the literature, several definitions exist for education and standardization. Standardization is a broader concept than the way it is defined 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 problems³ 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 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 and, per profession, contribute to transforming awareness into specific actions. The literature review highlights the relevance of EaS, the current challenges, outcomes from case studies, emerging topics, characterization of principal authors, and pedagogical approaches.

There are many reasons why one should have knowledge about standardization and standards, according to the literature, e.g.:

In an increasingly harmonized and globalized economy, Standards, Conformity Assessment and Technical Regulations have widespread implications for business and trade, the environment, societal well-being, technology transfer, innovation, and quality development (APEC 2009, p. 4).

Increased multi-disciplinary education on standardization provides the recipe for smoothing out the differences between standardization sectors and assures efficient and inclusive standards development processes (Kanevskaia, 2020, p. 162).

By familiarizing students and professionals with different aspects of standardization, we will prepare (future) experts for inevitable cross-sectoral cooperation and ensure increased quality and applicability of standards (Kanevskaia, 2020, p. 170).

Recent studies show that large companies are starting to understand that awareness of standards are even an asset for non-engineer employees dealing with the marketing of products (Jachia et al., 2020, p. 153).

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³ 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.

To have knowledge on standardization is important mainly because we live in a global world, where in order to be competitive, someone needs to speak a common language, and standardization could be this language. Higher education institutions have a great role in educating future professionals, but other NGOs and the industry itself could have their role too in increasing the awareness of the importance of standards (Puiu, 2020, p. 107).

On the other hand, drawbacks of EaS include less space for other relevant subjects in the curricula, and, as argued by Kanevskaia (2020), an equilibrium is necessary for EaS on inter- and multi- disciplinary programs; otherwise, the knowledge outcome might be impractical, superficial, and irrelevant. Despite several attempts to effectively increase the EaS provided at schools and universities, in practice, not much has changed in the last decades, and the systematic lack of awareness persists (Jachia et al. 2020; Kanevskaia 2020; Puiu 2020; Vasileva 2020; de Vries 2020b; de Vries et al. 2020). This issue is a call for the engagement of more actors and the development of strategies to foster EaS.

Authors have been looking at EaS from different perspectives in the academic literature. The main focuses are pedagogical approaches, curricula development, innovation, Sustainable Development Goals (SDGs), standard-specific courses, and case studies. Another topic observed was to which extent one should know about standardization. For example, engineers should have more than just awareness, since their daily tasks may involve highly standardized activities, such as quality assurance and metrology (APEC 2009; Van den Bossche 2020; ISO 2014; Mijatovic 2020). APEC presents “career roadmap and competence requirements for standards professionals” (APEC 2019), providing guidance for professionals working in companies or SDOs. A similar document was published by IFAN (2018). These guides help define what the students should know, and the variety of contents proposed exemplify the interdisciplinarity of standardization. For example, for someone that will work with marketing, IFAN (2018, p. 10) recommends a good knowledge of “why and how standardization can help sustainable development, taking into account in the strategy of a company in a changing world with limited resources”, and skills such as the “ability to apply sustainability and social responsibility to the marketing of products or services”.

Once an organization decides on what aspects of standardization should be taught in a given curriculum, it is crucial to determine how to teach students on the subject. The most common pedagogical approaches for incorporating EaS into curricula found in the literature are engaging content (e.g., with intense use of videos, pictures, and stories), serious games/simulation, workshops, case studies, and intensive writing. However, 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 of pedagogical approaches for specific audiences are employing engaging and appealing content in informatics and information systems (Fomin 2020), experiential and collaborative interdisciplinary learning in management education (de Vries 2020a), attracting the generation Z (Mijatovic 2020); hands-on case studies (Katusic et al. 2017), and the application of serious games in engineering education (Aydan et al. 2017; Calderón, Ruiz, and O’Connor 2018; García et al. 2020). It was also observed that while some academic programs include EaS as a specific discipline, most institutions integrate its concepts into existing curricula. In the Analysis’ section, professors with at least ten years of experience in teaching about standardization clarify the reasoning of employing such pedagogical approaches and how they include standards into their courses.

EaS is an instrument to foster a country's competitiveness in the global market. Other EaS advantages mentioned in the literature are economic development, more innovation, and potential help in addressing the SDGs in a long-term perspective. However, the main systematic challenges for teaching EaS are the lack of academic centres, standards courses, research in standardization, financial support, educational materials, institutional structure, students' appropriate background, and overall public awareness. 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, Blind, and Neustroev 2018), but also the governments (APEC 2009), universities (Katusic et al. 2017), industry (Puiu 2020) or even all these stakeholders, together (APEC 2008; Jachia et al. 2020; Puiu 2020; de Vries 2014, 2020b). In order to further understand the current EaS scenario worldwide and reflect on ways to improve it, it is necessary to investigate the initiatives of key EaS stakeholders in the global arena.

4.1 INITIATIVES ON EAS

Several initiatives to foster EaS have taken place worldwide in the last few years.

Firstly, there are initiatives from professors and educational institutions at the national level and some of these national level activities are very advanced. To provide just one example, EaS has been promoted as part of China's Belt and Road (B&R) initiative, which is a huge global infrastructure development strategy that was launched in 2013 (Anon 2022). B&R includes an investment in education, research, and academic exchange and 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 achievements include the realization of forums and academic conferences.

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 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. However, the group was disbanded in 2016 since some stakeholders preferred to address EaS as a national-level activity rather than a European one. 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).

The Asia-Pacific Economic Cooperation (APEC) and the Korean Agency for Technology and Standards (KATS) have jointly initiated a project entitled "APEC Strategic Standards and Conformance Education Program", which had its first publication 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).

The Education Guideline 1 (APEC 2008) provides a strategic curriculum model and guidance for implementing education programs about standards. Several highlights delivered are still current for EaS, such as the need to make attractive teaching materials, create case studies, develop target-oriented programs with clear objectives, employ hands-on learning (learning by doing), the need to train the teachers, consistent leadership, and collaboration. The second guideline (APEC 2009) presents a knowledge pyramid that defines the different characteristics of knowledge levels on a subject ranging from “unaware” to “expert”; the importance of “standards, conformity assessment, and technical regulations”; an overview of educational outreach efforts, including outreach strategies and preferred pedagogical methods; recommendations to organizations and universities; and their vision for the future of EaS. The third guideline (APEC 2010) is a 277-page higher and professional education textbook, “Standardization: Fundamentals, Impact and Business Strategy”. It includes nine case studies and a sample standard (ISO/IEC 27000). The fourth guideline (APEC 2011) compiles the lessons learned from 14 trial implementation programs. The fifth guideline (APEC 2015) explores the concept of a “Standards Professional” and provides a definition, analyses standardization job profiles (in the industry and SDOs), and make recommendations to APEC members. The latter is focused on stimulating EaS at the regional level. The recommendations are organizing a young generation program, engaging the young generation in international programs (such as the IEC Young Professionals programs), developing a professional database, organising the “teaching of teachers” programs, and promoting joint activities to raise awareness (in general). The sixth guideline (APEC 2019) provided a detailed career roadmap and competence requirements for standards professionals both in companies and in SDOs.

Thirdly, there have been a number of activities at the international level. The European Academy for Standardisation (EURAS) is the only international community of academic researchers in the field of EaS and their objective is to study standardization as a phenomenon rather than focus on technical research related to specific standards (de Vries et al. 2020). Until recently, there was also the International Committee for Education about Standardization (ICES), which was established in Tokyo in 2006 and brought together experts from academia and industry on a yearly basis to share ideas and experiences 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).⁴

Even intergovernmental organizations such as the United Nations have worked on EaS – the United Nations’ Economic Commission for Europe (UNECE) e Working Party on Regulatory Cooperation and Standardization Policies in 2012 (WP.6), which includes a

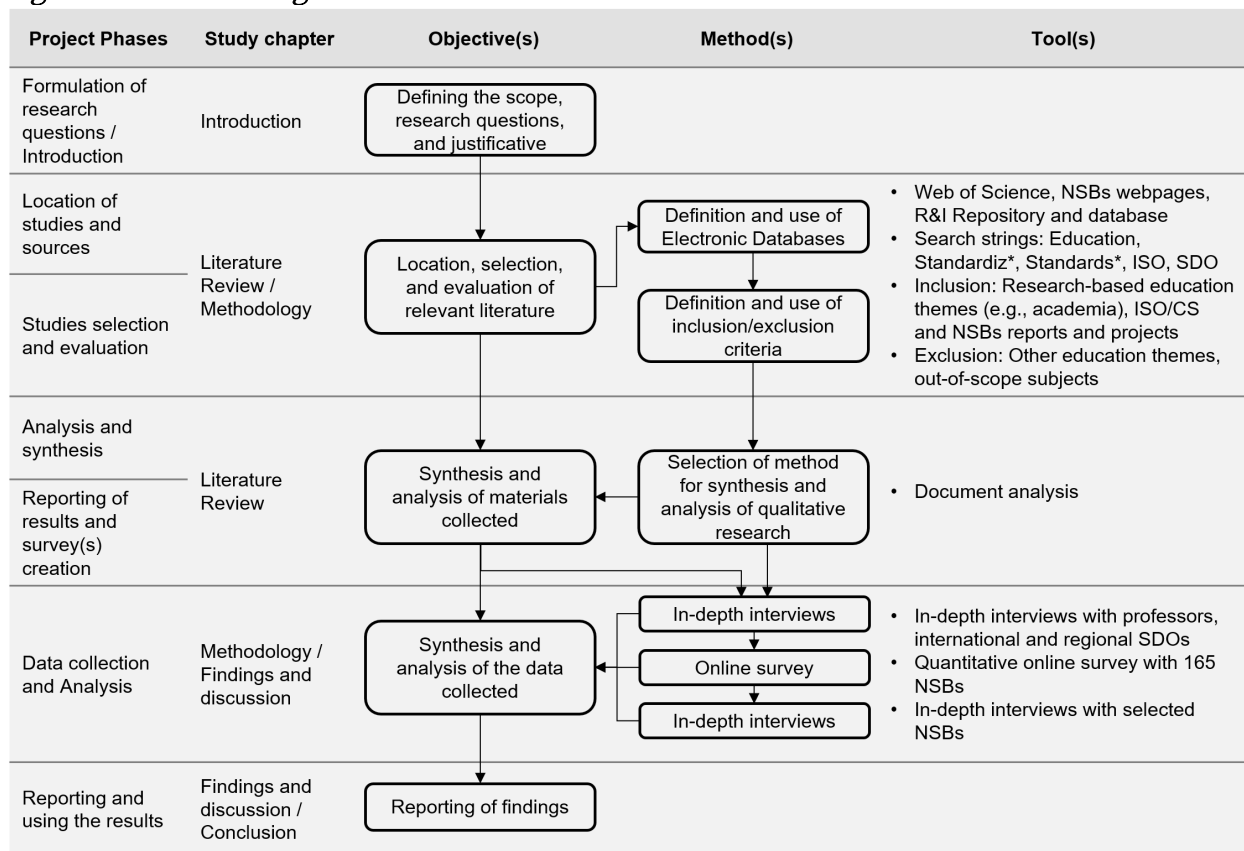
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⁴ Similar actions are noted at the national level as initiatives from SDOs (e.g., AFNOR n.d.; BSI n.d.; JSA n.d.).

group called ‘START-Ed’. This group works on promoting EaS through raising awareness, elaborating a module program on standardization, assisting and sharing best teaching practices and fostering cooperation with other organizations (UNECE n.d.). In total, six meetings have taken place (2013, 2014, 2015, 2019, 2020, 2021). The discussions at the WP6 2019 and 2020 sessions showed expanding interest in teaching standards from educational institutions. The START-Ed group is currently considering adding issues relating to the environment and to gender-responsive standards to the “UNECE model educational programme on standardization”, which has been used as a basis for a number of current teaching programmes in the UNECE region. Jachia et al. (2020) summarizes the initiatives of UNECE on EaS and concludes 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. 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.

5. METHODOLOGY AND CONCRETE TASKS

To collect data about EaS practices, we interviewed stakeholders from regional and international SDOs, professors, and other institutions, distributed a web-based survey, and interviewed NSBs. 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.

Figure 1 – Methodological framework



5.1 PROJECT PHASES

The formulation of research questions was initially based on the gaps identified by the ISO/CS R&I unit in a scoping exercise entitled the “Education workshop 2020”. Ten experts, including professors, specialists in standardization, ISO/CS employees, and NSBs employees, all experienced in EaS, participated.

The location, selection, and evaluation of studies were performed by 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*”, “education* and standardis*”, and other combinations of these keywords.

Next, criteria for exclusion of articles were considered (e.g., out-of-scope subjects) by reading the summary of the articles. Finally, the second selection of papers was performed, looking at the references of the articles selected, the database of the ISO/CS R&I unit, and ISO's repository of teaching materials (ISO, n.d.).

The documents' analysis and synthesis and the scoping exercise findings led to the elaboration of the online questionnaire and interview guidelines. The information gathered from the articles were: the relevance of EaS, EaS challenges, emerging EaS topics, proposed solutions for fostering EaS, course topic or proposal, a summary of the proposal, focus area (paper), learning outcomes, audience, pedagogical approaches used, type of knowledge, and teaching topics, and data about the authors (e.g., filiation, email).

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 international and regional SDOs.
2. Web-based survey to identify and map current projects related to EaS while understanding the needs, perspectives, insights, and recommendations from NSBs.
3. In-depth semi-structured interviews via videoconference with selected NSBs. The objective is to find best practices to foster EaS.

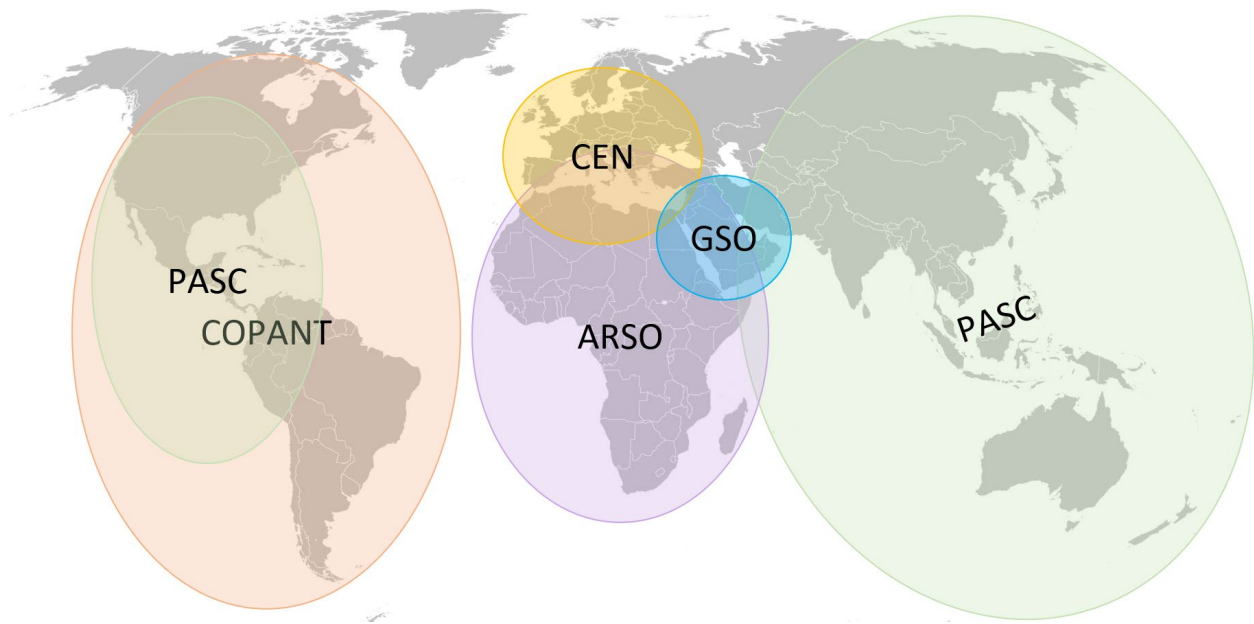
The results and analysis summarize the findings, investigate the perspectives and actions of ISO members and other key stakeholders regarding EaS, and suggest strategies to foster EaS. Finally, an education strategy is proposed to ISO that states which projects should be developed to help the NSBs foster EaS in their national contexts.

6. RESULTS AND ANALYSIS

6.1 DATA FROM PHASE 1: INTERVIEWS

The interviewees were divided into two groups: one with stakeholders that represented the view of their institutions (international and regional SDOs), and another for professors/researchers, which expressed their personal opinions on the theme. A total of 13 in-depth semi-structured interviews were performed 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. 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 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. The professors were from the Erasmus University (Netherlands), Berlin Institute of Technology (Technische Universität Berlin, Germany), University of Geneva (Switzerland), and Emlyon Business School (France). In addition, another three organisations were also interviewed: IEC, UNECE, and the International Federation of Standards Users (IFAN).

Figure 2 – Regional Standards Organizations interviewed



6.1.1 APPROACHES TO EAS

The international and regional SDOs believe that in EaS, the focus should be on a basic understanding of standards (awareness), including its application and benefits, and understanding how stakeholders can participate in the standardization process. One of the interviewees highlighted that it is essential to remember that 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 to the policy content, training and

education, and the relevancy and application of standards for business in particular SMEs. The respondents, especially the ones from developing regions, highlighted the importance of EaS and standardization for facilitating global trade.

On the other hand, the professors interviewed highlighted that it is crucial to differentiate the possible approaches to teaching standards, e.g.:

- 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.
- 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.

6.1.2 EAS ACTIVITIES

When inquired 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, a suggestion of curricula for courses and Master's programs, online training, role-playing games, support to undergraduate projects, and essay competitions. These initiatives had policymakers, industries, NSBs, and universities as primary target groups. The outcomes of these activities and materials developed were a higher awareness from policymakers, higher involvement of NSBs and SDOs in teaching activities at universities, a higher interest in EaS from the industry and experts. As an organizational goal, EaS was classified as a highly relevant subject. Strategically, some regional SDOs said they are waiting for an initiative from ISO to follow and contribute more to the field.

All respondents have developed teaching materials. However, it is also highlighted that 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)⁵.

●
⁵ 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.

Correspondingly, the literature underlines that the biggest Generation Z students challenge is to keep them actively involved and interested in the subject (van de Kaa 2020; Mijatovic 2020). The respondents argued that the best approach to address this challenge is:

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).

Their recommend to link the students' interest to standardization (e.g., sustainability crisis, COVID-19) and clearly show the link between standards and the subject addressed (in an embedded course's case). 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 to reach practical applications of standards with which the students are familiar, and based on real-world, understanding that people, processes, and organizations do not always work as expected (Fomin 2020; Mijatovic 2020).

The professors interviewed demonstrated their preference for pedagogical approaches such as problem-based learning, in-class; active learning, in-class (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. These are in line with the literature that suggests these methods as being the most appropriate for EaS (Aydan et al. 2017; Mijatovic 2020; de Vries 2020a).

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. Although some professors had previous experience working in SDOs, none were currently involved standards development process. Van den Bossche (2020) is an example of this.

6.1.3 CHALLENGES

When inquired about the challenges they have encountered in terms of their work on EaS or promoting EaS, the SDOs highlighted the lack of: a formal strategy to foster EaS (consistency in long term projects, a formal timeframe, clear objectives, and outcomes); awareness of the EaS' importance by policymakers; experts in the field; and financial resources. The main challenge for professors is the lack of support and awareness from all stakeholders involved, from students to SDOs.

Solutions were proposed to overcome these challenges. First, despite the fact that standardization is everywhere, people in general, including students, don't know about them. Due to the systematic lack of awareness, it is difficult to "convince the students" about the subject's importance and get attendance in the standards-related courses. Suggestions to attract students are to offer a standardization certificate that the NSB could recognize,

advertise the course, and foster research about the theme. This certificate could also be an outcome of common curricula for standardization courses recognized at the international, regional, and national levels. In addition, respondents highlighted the need for more cooperation among stakeholders. Finally, they believe that standards should be introduced at all educational levels, but in particular, at the undergraduate, graduate, and post-formal levels:

In the beginning, it was complicated because it was a new course. A strategy is to start by offering it as an elective course – the attendance is usually low – but it grows with time (U-R01).

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 the professors' activities through research, advertisement, and increasing awareness about the subject's importance at all levels. The SDOs should act in a structured manner, following a strategic EaS to better support other SDOs and NSBs.

EaS can be promoted by means of extracurricular activities, awareness-raising targeted at policy makers, cooperation among institutions, online teaching, and involvement of researchers in standardization activities and experts in teaching activities.

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).

6.1.4 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 respondents from regional and international SDOs believe that their organisations should provide teaching materials and related resources, engage with academic stakeholders to encourage the inclusion of EaS in their programs, organize public events, promote cooperation with NSBs and within NSBs, promote EaS among policy makers, and create and implement a formal EaS strategy. Additionally they suggest these organizations to:

- develop strategy, an action plan and further projects;
- stimulate research on teaching approaches and topics, prioritizing innovative pedagogical approaches;
- develop teaching materials and learning resources in cooperation with NSBs;
- foster cooperation their national members and harmonize efforts;
- share lessons learned and best practices;
- develop partnerships with industry associations at the regional level;
- provide training for current and potential participants in international standardization.

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 the standardization meetings;
- make cooperation agreements with universities to help the development of standardization as an academic discipline.

The NSBs should have at least one person working full time on EaS, focusing on building partnerships and raising his NSB's awareness. The NSB is recommended to cooperate with other NSBs and SDOs. It may play a coordinating and stimulating role, be in touch with ministries of education and other stakeholders such as consultants. It is advised to regularly share their activities on social media.

The main actions listed for universities are focused on research and teaching activities related to standardization to students and professors, the support to undergraduate postgraduate projects related to standardization, and the development of programs for young professionals.

6.1.5 NEXT STEPS

The respondents started by highlighting the importance of a more robust body of knowledge and 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 pressure from the labour market and the public in general to include EaS into the curricula. Another respondent proposed a top-down approach in which the ministers of education would recommend to the universities to teach EaS. However, in most countries because universities have the autonomy to decide about academic education content. The third set of suggestions is around the NSBs building relationships with education ministers and universities under a global strategy proposed by international SDOs. The idea is to raise awareness, build partnerships with these stakeholders, and gradually reach the students.

In terms of how to introduce standards into curricula, there were two types of suggestions. The first was related to convincing professors of the value of teaching standards (since, if they cannot be convinced of this, it will do little good to develop great teaching materials). Suggestions here included offering activities with professors as the primary target group to discuss the benefits and drawbacks of standardization (e.g., webinars, participation in congresses), as well as directly fostering research in the field through research grants, joint master programs, etc. The second was related to development and organization of the curricula material itself. Here, interviewees proposed focusing efforts on developing quality teaching materials and case studies that could be applied to a professor's teaching subject. It was suggested that standards could be a horizontal subject, introduced at the beginning of every academic program (e.g., a general module focused on presenting the standards

students interact with in their everyday life). This subject should not cover overly technical topics and, in terms of teaching approach, should use pedagogical approaches appropriate for generations Z and Alpha (a gap also observed in the literature, e.g. Fomin 2020; Kanevskiaia 2020; Mijatovic 2020).

Ideally, the respondents would like to see at least one course of standardization integrated into every basic curriculum (even if as an elective course).

In conclusion, the interviewees pointed out the inadequate number of initiatives in recent years and called for urgent action. They believe that the SDOs should take the lead, whilst highlighting the importance of developing and following strategies for EaS in order to ensure a systematic and coordinated approach to fostering EaS worldwide.

6.2 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 165 NSBs (all ISO members). 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 54.54% (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

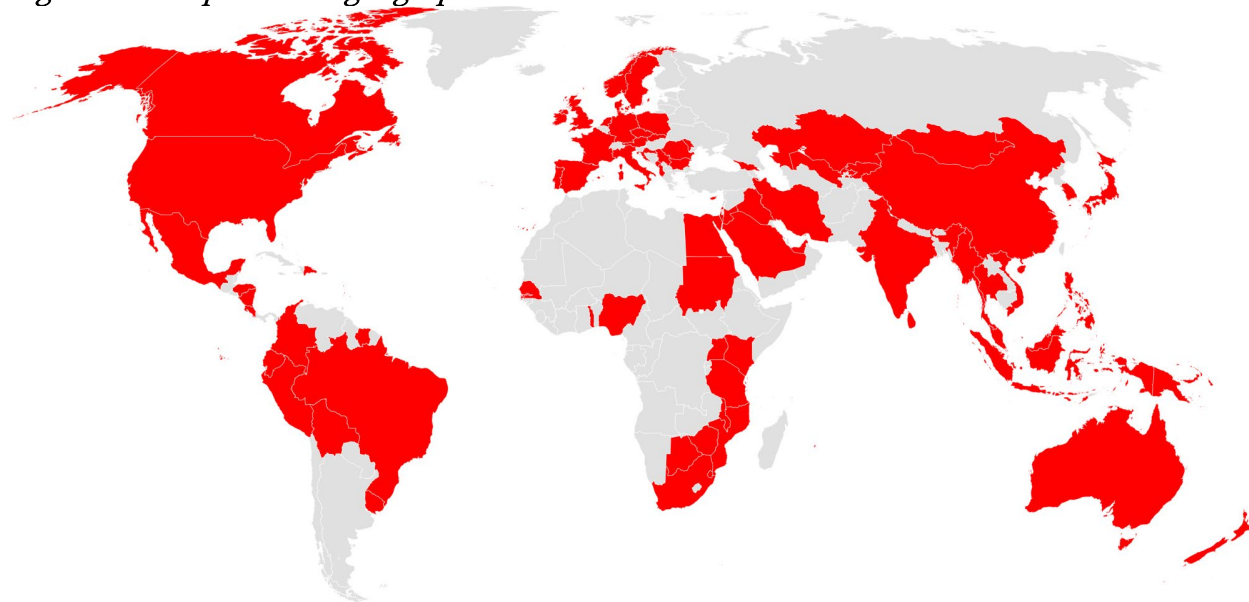


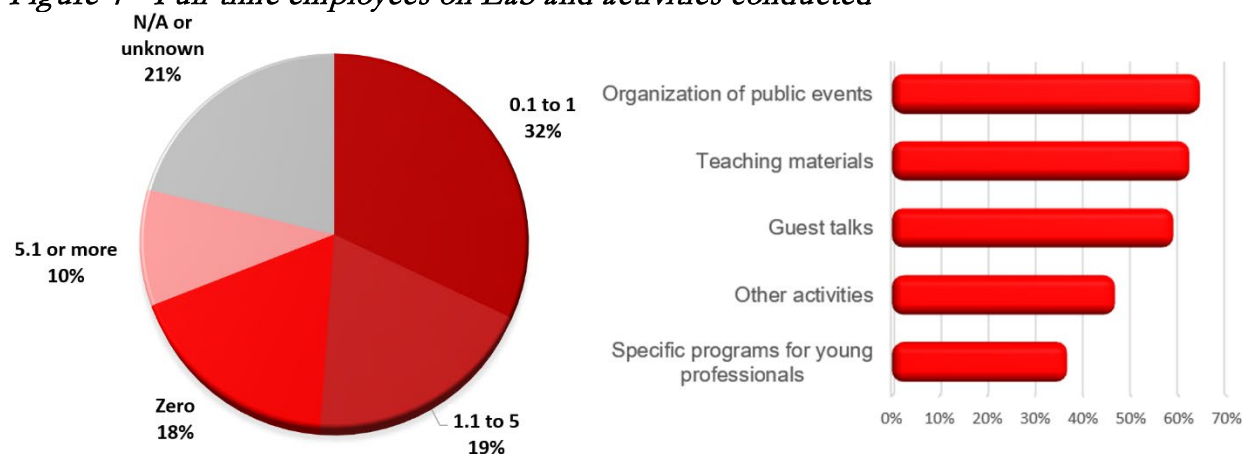
Table 1 – Respondents' countries and regions

Re- gion	Number of coun- tries	Country list
Africa	17	Botswana; Egypt; Eswatini; Gambia; Kenya; Malawi; Mauritius; Mozambique; Nigeria; Senegal; Seychelles; South Africa; Sudan; Togo; Uganda; United Republic of Tanzania; Zimbabwe
Amer- icas	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	28	Azerbaijan; Bahrain; Brunei Darussalam; China; Cyprus; 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	24	Albania; Austria; Bulgaria; Croatia; 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	

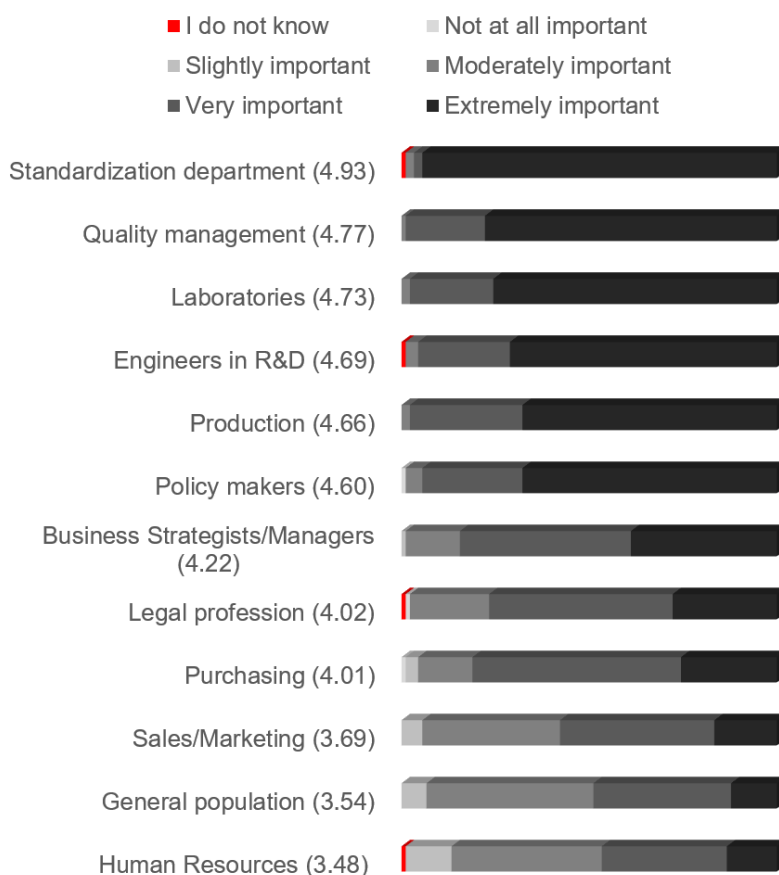
The respondents were composed mainly of NSBs' directors (44%), heads (17%), and managers and specialists (20%). A total of 89% replied that they had undertaken activities related to EaS in the last five years, such as the development of teaching materials and guest lectures at universities. The respondents 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 inquired 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%, are composed mainly of participation in specific projects, workshops, and training programs.

Figure 4 – Full-time employees on EaS and activities conducted



The respondents considered it extremely important that professionals understand standards and standardization. Figure 5 ranks the awareness importance according to the area, 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 various 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 and Drechsler 2020; IFAN 2018).

Figure 5 – 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, 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 students’ 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 addressed in the Discussion section.

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

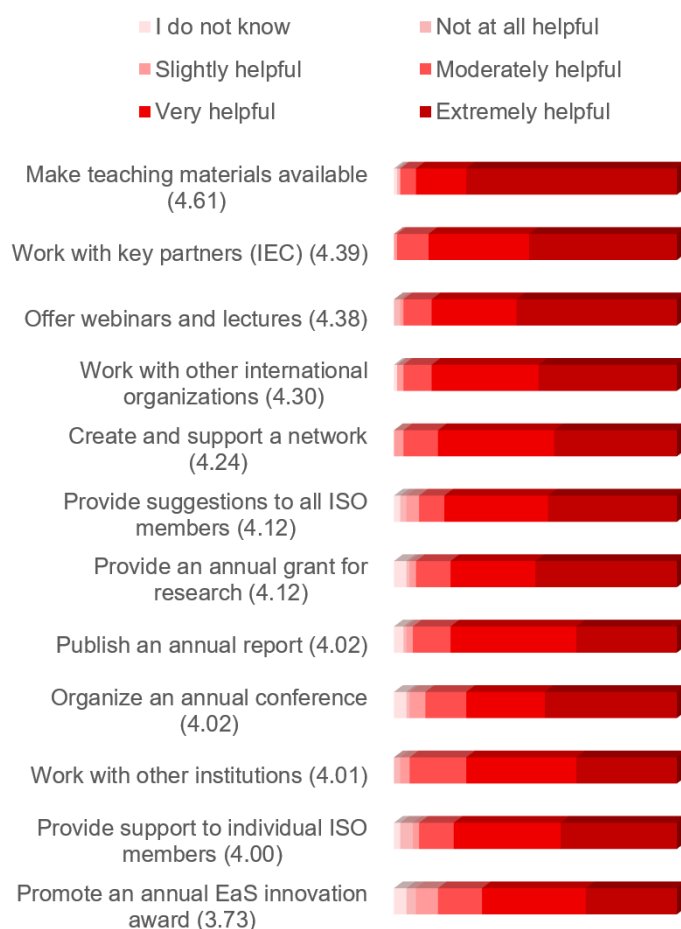
Proposed action	Int. SDOs	Reg. SDOs	NSBs ⁶	Universities
Conduct research on teaching approaches and topics	72%		69%	80%
Provide teaching materials and other resources	74%		90%	59%
Engage with academic stakeholders to encourage the inclusion of EaS in their programs	52%		91%	54%
Conduct guest lectures	51%		90%	56%
Invite students to observe standards-related activities	40%		93%	56%

⁶ NSBs = National Standards Bodies OR SDOs at the national level.

Allow and promote visits of students to NSB offices	22%	91%	64%
Promote student participation in internship projects	43%	82%	79%
Support postgraduate projects	49%	83%	78%
Support undergraduate projects	37%	86%	76%
Organize public events (e.g., Webinars)	76%	93%	62%
Host and promote podcasts	68%	76%	49%
Develop specific programs for young professionals	76%	76%	56%
Provide standards to universities for free or for a reduced fee	54%	89%	18%

Figure 6 summarizes the actions NSBs believe that ISO could do to assist them in promoting EaS in their national context. The responses were classified as “not at all helpful” to “extremely helpful”, represented on a 1 to 5 scale. The values in brackets represent the scoring average. The most prominent elements are making teaching materials available (4.61), working in partnership with IEC (4.39), and offering webinars and lectures (4.38). Preliminarily, recurrent comments include that NSBs are excited about ISO’s initiative to develop an education strategy and enthusiastic about participating; and that it will be important to consult ISO members and regional SDOs to ensure that the initiatives do not overlap (instead, complement each other).

Figure 6 – Actions suggested for ISO



6.3 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 the best practices. However, it is not easy to assess what is ‘best’ because situations differ and 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 applied a ‘quick and dirty’ method to classify the countries, in order to invite the ‘best’ ones for the interviews in phase 3. The classification criterion was a weighted average of the following variables: 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. It was observed that Asian countries had a significantly higher score when compared to the other regions. Further development of an evaluation model will help to understand why and how they have achieved success in fostering EaS. 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 phases 1 and 2, and argue whether those actions would help foster EaS in their national contexts.

The majority of suggestions to foster EaS in practice had an overall agreement by NSBs. The highlights are:

- Research is needed: Standardization is undoubtedly important; however, is it more important than the topics already present in the educational curricula worldwide? It is definitely becoming more important with advances in globalization and sustainable development. The interviewees called for more research about standardization’s impacts.
- 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 a language constraint 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.
 - Nevertheless, in order to adequately support professors, teaching materials should be available in tandem with research incentives.
 - It is important to have part of the repository dedicated to materials for children and teenagers.
 - It is important to include a course on how to use the materials or indicate which materials are made for professors.
 - The materials should consist of standardization plus another theoretical element, such as quality management, sustainable development, etc.

- Research Network: NSBs and professors could be organized in an online forum for exchange experiences, materials, case studies, etc. However, a small number of members per country (three to five) is preferable to foster active participation.
- Maturity model: The development of a methodology to assess a country's EaS development level and understand the challenges and opportunities to integrate EaS in different education systems. SDOs 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: Most interviewees had education set as an important topic in their organizational strategies. However, only the Asian respondents had specific – and updated – strategies for developing EaS in their national context. With clear goals and outcomes, these formal strategies were pointed out as a crucial action for fostering EaS.
 - In addition, NSBs should allocate budget and personnel to EaS.
- Partnerships with educational institutions: MoUs (Memorandum of Understanding) and any form of cooperation is helpful to make standardization part of the academic curricula.

In contrast, interviewees disagreed on some specific actions:

- “Standards should be cheaper to students”. There is no agreement on whether standards should be cheaper or “free” for students. The supporting argument is that students should have access to real standards for an experience closer to what they will find in the industry. However, some professors interviewed in phase 1 argued that they do not use standards in their teaching due to its complexity and, in some cases, high abstraction. Finally, other interviewees pointed out that there are already many standards freely available in the market (e.g., standards related to the COVID-19 mitigation efforts).
- Some interviewees asked for materials with the basis of standardization and case studies for professors. However, such materials already exist and are freely available. Unfortunately, they are scattered through different entities worldwide (e.g., AFNOR n.d.; APEC 2010; BSI n.d.) and in many languages (e.g., JSA n.d.). Therefore, relatively difficult to access.

NSBs were inquired 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 on 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 into their curricula?

- Would the 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. For example, webinars, workshops, and conferences.
- demand active participation and collaboration of international and regional SDOs 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 the 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.).
 - Make use of online tools for reaching a broader audience.
- Provide direct support to research (e.g., scholarships, guidance in thesis and dissertations, share data, etc.).
 - Students should 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. These should include 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.
 - COVID-19 related courses should be elaborated for helping to prevent and mitigate future pandemics and related emergencies.
 - Provide training focused on "young professionals" in standardization. These are professionals that have just started working in the field regardless of their age.

6.4 DISCUSSION

6.4.1 NEED FOR EAS

Based on a survey among NSBs and two rounds of expert interviews, this study seeks to provide insights in practices of EaS and the role of NSBs in stimulating EaS. The empirical data confirm the insights from the literature about the increasing importance of EaS and the need to stimulate it. NSBs demonstrate a very positive attitude and interest. However, an apparent discrepancy exists when comparing this attitude with NSBs' actions. 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. 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 the most efficient ways to foster EaS worldwide.

6.4.2 WHAT SHOULD BE ACHIEVED (WHAT WE WOULD LIKE TO ACHIEVE?)

As demonstrated in the literature, there is no consensus regarding the best strategies to foster EaS among young people. Therefore, we investigated and summarised stakeholders' ideas, perspectives, and best practices. Among them, an overall agreement was observed in the long-term objectives for EaS. At the national level, it is necessary to attract the next generation of students and to; raise the awareness of a wide variety of stakeholders – academic stakeholders (e.g., professors, research project coordinators, program directors, etc.), employees at all levels, policy-makers (in special particular, ministries of education), and the NSB managements. At the regional level, regional SDOs must recognize the importance of EaS, define clear EaS objectives in a strategic plan, and coordinate the efforts of their members to make progress in the field. International SDOs must equally develop a plan with clear outputs and outcomes and effectively support their members and regional organizations, while coordinating the global efforts to improve EaS worldwide. At all levels, it is necessary to support the professor's teaching and research activities in standardization.

6.4.3 POTENTIAL SOLUTIONS FOR FILLING THE GAP

A first challenge is to raise students' awareness of standards. The level of awareness to be achieved depends on the academic course and aimed professional path (e.g., APEC 2019; IFAN 2018). It was identified, similarly to ISO (2014), four main approaches to teaching standards: teaching about standards embedded in courses dealing with specific disciplines; in dedicated lectures about standardization that can be used in the context of different

courses; as a part of an academic curriculum; and as one of the main subjects in a specialized academic curriculum. Pedagogical approaches observed as solutions to raise students' awareness concentrate on creating engaging content, experiential learning, serious games, real-world and global content, case studies, internships, workshops, active teaching, discussion, and problem-based learning in class. However, to be effective, the solutions must include all standardization stakeholders (industry, SDOs, academia, governments, and other educational institutions). Overall, the interviewees point out the following solutions to be performed by all stakeholders to raise global EaS awareness:

1. We must better understand the needs for EaS (current and future standardization issues and needs).
2. Foster education through research, support to professors, training activities.
3. Foster exchange between standardization professionals and professors; NSBs and governments; NSBs and universities; NSBs and other SDOs.
4. Divulgate the potential of standardization, its benefits and drawbacks to students and professionals.
5. Determine clear objectives for the future by elaborating strategies at the global, regional and national levels. These strategies must change according to the national education systems. In addition, they must include in the scope actions for primary and secondary schools.

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

6. Stakeholders should continue and offer support to current EaS actions;
7. Cooperate to build capacity, so relevant institutions can build up expertise and elaborate their own teaching and materials;
8. In the actions to foster EaS, give emphasis to new standards-related areas, such as sustainable development, gender equality, etc.

Below we suggest practical ideas on how these actions could be executed based on the academic literature and interviewees' responses.

6.4.4 OPERATIONALIZING THE SOLUTIONS (CONCRETE ACTIONS)

How do we operationalize the solutions suggested in the literature and the stakeholders interviewed? For attracting the next generation of students, it is vital to make use of appropriate pedagogical approaches; recognize the importance of standardization in topics related to engineering and management – but also human sciences and other disciplines as long as the content is adequate to the target group; work to raise the awareness of professors, universities, and companies; explore the opportunities arising with online learning in COVID times; develop novel materials – focused on serious games, online presentations, case studies, and engaging content; and the relationship between standardization and the SDGs.

More specifically, the stakeholders interviewed highlighted the critical actions universities, NSBs, and SDOs should take. Universities should conduct research on EaS teaching strategies and topics while promoting undergraduate and graduate projects (in practice, adding standardization in the curricula) – in a contextually relevant manner. The NSBs should also

conduct research on EaS teaching strategies and topics. In addition, they should provide teaching materials and other resources to support teaching activities, engage with academic stakeholders to encourage the inclusion of EaS in their programs, and promote EaS among their peers (awareness-raising). Finally, regional and international SDOs should equally provide teaching materials and other resources to support teaching activities and engage with academic stakeholders to encourage the inclusion of EaS in their programs. In addition, it is recommended to organise public events (e.g., Webinars, Workshops), foster more cooperation on EaS among international and regional SDOs and NSBs, promote EaS among NSBs, and create a formal EaS implementation and development strategy. Thus, SDOs should act in a structured manner, following a strategic plan which would offer better support to other SDOs and NSBs in EaS activities.

Another set of recommendations is focused on the interaction of multiple stakeholders (governments, industry, academia and SDOs to foster EaS) rather than looking at them individually, both from the respondents and the literature (e.g., Choi and de Vries 2013; Mijatovic 2020; de Vries 2014). These actions are an operationalization of the solutions mentioned previously (presented in the same sequence):

1. ***Understand the needs for EaS:*** foster exploratory research about standardization and EaS status at the national level. For example, by investigating the benefits of standardization, mapping the current EaS level in a given country and variables such as economic development (e.g., a maturity model);
2. ***Foster research and teaching:*** developing relationships with universities and schools through cooperation and making teaching materials available. For example, signing MoUs (Memorandum of Understanding); and creating a database of teaching materials to professors and students (ISO 2014; Puiu 2020).
3. ***Foster exchange between stakeholders:*** promoting a network of people interested in the subject and partnerships with and within institutions to enable experience and knowledge sharing while contributing to the further development of the field (de Vries et al. 2020). For example, creating or strengthening communities of practitioners at the national and international levels (e.g., de Vries, Trietsch, and Wiegmann 2020); and creating and maintaining a network between researchers and professionals (e.g., ISO 2014).
4. ***Organize public events:*** to share the potential of standardization raise awareness while strengthening the connection between standardization, research, and education. For example, organization of workshops with different target groups (students, researchers, professors, professionals, policy-makers, NSBs, and SDOs); campaigns to promote the role of standards to raise the population awareness (e.g., Puiu 2020); and promote national, regional, and international standardization competitions.
5. ***Create strategies:*** SDOs at the international, regional, and national levels should elaborate strategy in cooperation with the governments, industry and other stakeholders with clear goals and deliverables at the global, regional and national levels (e.g., APEC 2009; de Vries 2014). It is essential to understand your stakeholders before developing a strategy – vide item 1.
6. ***Build awareness:*** keep current activities develop new ones while investing in ongoing support.
7. ***Cooperate to build capacity:*** help other institutions to build up expertise for teaching and elaborating their materials.

8. *Highlight the importance of standardization in the international arena:* In all activities, link standardization to sustainable development, gender equality, etc.

6.4.5 THE ROLE OF STAKEHOLDERS ON EAS AT THE DIFFERENT LEVELS

The data collected reveals what should be done by stakeholders at the national, regional and global levels to foster EaS in their geographical contexts. Some Asian countries have notably achieved success in implementing EaS in their educational systems. The main stakeholders at the national level are the government, educational institutions, the industry, and local SDOs. As observed in Asia, all these stakeholders should work to implement EaS into the academic curricula at all educational levels. If one fails to adhere to the cause, either due to lack of awareness or for any other reason, EaS is unlikely to be successfully implemented nationally. The research concludes that NSBs should take the initiative to approach ministries of education and universities to network and build partnerships. NSBs can interact with governments by participating in public events, seminars, congresses, and strategic meetings. From NSBs to universities, they should start by building relationships with professors either by providing educational materials, making data available for research, participating in congresses and conferences, offering internships, or any kind of financial support. Certain elements increase the NSB success in building such relationships (best practices). Namely, a national EaS strategy with clear outputs and outcomes, sets of educational materials for professors, 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 the various industry sectors to investigate their perspective and interests in EaS, considering they are primary beneficiaries and contributors to standards and standardization.

At the regional level, there is a very diverse group of SDOs, and one of the main differences is in how active they are in stimulating EaS. For example, among the interviewees, GCC Standardization Organization (GSO) is the most active in EaS, whereas CEN/CENELEC is the most active in other areas overall, but not anymore in EaS. Also, at the national level there is no direct link to the amount of EaS and how active the country is in other standardization activities. Another highlight is that in the case of Asia and parts of the Americas and Oceania, the APEC cooperation is not an SDO but fosters EaS cooperation at the regional level. Considering these variations between regions, we recommend coordinating and supporting the EaS development. This will help align the national strategies and elaborate regional EaS development plans. Strategic alignment will facilitate the exchange of professionals and students among the countries, raise students' and professors' interests, and monitor progress. This could be reinforced by implementing recognized certificates in standardization areas for students, organizing regional events, and promoting communities of people interested in EaS.

At the international level, international SDOs and organizations may concentrate their efforts on activities that cannot be done by the stakeholders previously mentioned. These activities are the development of global EaS strategies that coordinate the regional and national efforts; conduct research on a worldwide scale about impacts, benefits, and approaches to foster EaS; raise awareness by promoting events (groups include policy-makers, professors, professionals, industries, NSBs and regional SDOs); facilitate the interaction of people interested in EaS; offering support to other SDOs and NSBs (sets of courses,

materials, presentations, and lecturers); development of strategic partnerships; and foster research (providing data, materials, knowledge, or financial support). It was observed that the countries' level of involvement in EaS varied (e.g., Japan, China and the Republic of Korea are more active than the other countries surveyed), and it is not clear which factors lead to these variations and what could be done to enhance EaS involvement. This is a topic for future research, it might result in the development of an EaS maturity model.

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 to other relevant organizations; thus, their actions can be impactful and relatively simple initiatives can significantly contribute to EaS development. Potential initiatives identified are making teaching materials available (to professors and students) by updating and upgrading the current ISO repository; promoting EaS forums and networks; fostering and developing research at the global scale; developing global EaS strategies; and promoting online events (webinars, workshops, conferences, etc.).

Based on the suggestions compiled in Figure 6, the comments provided by in the survey and by interviewees, and the analysis of this work, we propose the ISO Education Strategy. Appendix D contains a summarized (non-confidential) strategy version. This strategy outlines which projects ISO should develop to help NSBs to foster EaS in their regions.

6.4.6 THE FUTURE OF EAS

We mention several initiatives to foster EaS from actors such as EURAS, ICES, WSC, APEC, national, regional, and international SDOs. However, actual implementation of EaS is lagging. Many of the practices, ideas and initiatives we found are not new, most of these were already mentioned by de Vries and Egyedi (2007). Meanwhile the importance of standardization is growing further and thus the relevance of EaS. Thus, it is still necessary to leverage EaS worldwide to boost the use of standards and, therefore, help address global challenges such as climate change, gender inequalities, and economic development. While more initiatives are needed, it is essential to understand the issues that arise with them. First, education is not neutral, and EaS can be used as an instrument to support specific ways of standardization. Second, education is a country-level activity; therefore, global initiatives should depart from a neutral organization with worldwide representation and then be adapted by the competent SDOs and organizations to the national level. Based on the data collected, the best candidates to issue global EaS initiatives are ICES (however, they were not active when this article was written), ISO due to its neutrality and international coverage, or the WSC (the World Standardization Cooperation between ISO, ITU and IEC). Even though IEC and ITU are sector-specific, WSC is a candidate since education is one of its core topics. Finally, even with a global push, the objective of fostering EaS worldwide can only be achieved by active cooperation and participation of all stakeholders involved, governments, educational institutions, SDOs, and the industry, as proposed in the section above. In addition the new *Journal of Standardisation* can play a role as well, by reporting about initiatives to foster EaS, by publishing scientific studies on EaS, and by being an outlet for standardization research as such – in the development of both an academic discipline and a profession, both research and education are needed and re-enforce each other.

7. CONCLUSION

Because of standardization's increasing importance, EaS is crucial. Unfortunately, current initiatives have not been effective in raising global awareness about standardization. Therefore, our study seeks to provide a basis for fostering EaS by studying literature, asking interviewing core experts in the field, making and inventory of NSB practices and suggestions, and tracing and analyzing best practices. Based on this, we suggest ways to accelerate the transition towards a world with more EaS to allow business and society to better reap the benefits that standardization can provide.

The main limitation of this research is that, despite the high response rate, our global survey 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 in 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 and stakeholders have been clear that, despite the large number of existing activities/materials on EaS, this is still not enough. There is still a gap between what exists and what is needed.

REFERENCES

- AFNOR. n.d. "Enseigner La Normalisation - AFNOR Normalisation." Retrieved January 31, 2022 (<https://normalisation.afnor.org/enseigner-la-normalisation/>).
- Anon. 2021. "The 3rd B&RUAS Summit Forum on Standardization Education and Research Cooperation Successfully Held." *China Jiliang University*. Retrieved January 25, 2022 (<https://english.cjlu.edu.cn/newsshow.html?id=472>).
- Anon. 2022. "The Belt and Road." *Belt and Road Portal*. Retrieved January 25, 2022 (<https://eng.yidaiyilu.gov.cn/ztindex.htm>).
- APEC. 2008. "APEC - Education Guideline 1: Case Studies of How to Plan and Implement Standards Education Programs and Strategic Curriculum Model." (March). Retrieved January 18, 2022 (<https://www.apec.org/publications/2008/03/education-guideline-1-case-studies-of-how-to-plan-and-implement-standards-education-programs-and-str>).
- APEC. 2009. "APEC - Education Guideline 2: APEC Strategy for Education and Outreach on Standards, Conformity Assessment and Technical Regulations." Retrieved January 18, 2022 (<https://www.apec.org/publications/2009/07/education-guideline-2-apec-strategy-for-education-and-outreach-on-standards-conformity-assessment-an>).
- APEC. 2010. "APEC Education Guideline 3 - Textbook for Higher Education - Standardization: Fundamentals, Impact and Business Strategy." 277. Retrieved January 18, 2022 (<https://www.apec.org/publications/2010/06/education-guideline-3-textbook-for-higher-education-standardization-fundamentals-impact-and-busines>).
- APEC. 2011. "APEC - Education Guideline 4. Teaching Standardization in Universities: Lessons Learned from Trial Program." (October). Retrieved January 18, 2022 (<https://www.apec.org/publications/2011/10/education-guideline-4-teaching-standardization-in-universities-lessons-learned-from-trial-program>).
- APEC. 2015. "APEC - Education Guideline 5. Inspiring the Next Generation of Standards Professionals : Towards Job Profiling in Today ' s Global World." (March). Retrieved January 18, 2022 (<https://www.apec.org/publications/2015/03/education-guideline-5-inspiring-the-next-generation-of-standards-professionals-towards-job-profilin>).
- APEC. 2019. "APEC - Education Guideline 6. Career Roadmap and Competence Requirements for Standards Professionals." (August). Retrieved January 18, 2022 (<https://www.apec.org/publications/2019/08/education-guideline-6---career-roadmap-and-competence-requirements-for-standards-professionals>).
- Aydan, Ufuk, Murat Yilmaz, Paul M. Clarke, and Rory V. O'Connor. 2017. "Teaching ISO/IEC 12207 Software Lifecycle Processes: A Serious Game Approach." *Computer Standards and Interfaces* 54:129–38. doi: 10.1016/j.csi.2016.11.014.
- Blind, Knut, and Sandra Drechsler. 2020. "Necessary Competences of Employees in the Field of Standardization." Pp. 113–37 in *Sustainable Development Knowledge and Education About Standardisation*.
- Blind, Knut, and Philipp Heb. 2021. "Standardization and Sustainability: Stakeholders' Perspectives." *EURAS Proceedings 2021: Standardisation and Innovation* 111–26.
- Blind, Knut, Florian Ramel, and Charolotte Rochell. 2021. "The Influence of Standards and Patents on Long-Term Economic Growth." *Journal of Technology Transfer*. doi: 10.1007/s10961-021-09864-3.
- Van den Bossche, Peter. 2020. "A Look Behind the Curtain: Standardization Education for Engineers from the Electric Vehicle Standardization Shopfloor." Pp. 17–29 in.
- BSI. n.d. "Education | BSI." Retrieved May 14, 2021 (<https://www.bsigroup.com/en-GB/about-bsi/uk-national-standards-body/what-is-the-national-standards-body/education/>).

- Calderón, Alejandro, Mercedes Ruiz, and Rory V. O'Connor. 2018. "A Serious Game to Support the ISO 21500 Standard Education in the Context of Software Project Management." *Computer Standards and Interfaces* 60:80–92. doi: 10.1016/j.csi.2018.04.012.
- Choi, Dong Geun, and Henk J. de Vries. 2013. "Integrating Standardization into Engineering Education: The Case of Forerunner Korea." *International Journal of Technology and Design Education* 23(4):1111–26. doi: 10.1007/s10798-012-9231-7.
- Curtis, H. L., L. Catalani Gabriel, M. Sahakian, and S. Cattacin. 2021. "Practice-Based Program Evaluation in Higher Education for Sustainability: A Student Participatory Approach." *Sustainability (Switzerland)* 13(10816).
- European Commission. 2022. "An EU Strategy on Standardisation: Setting Global Standards in Support of a Resilient, Green and Digital EU Single Market." Retrieved February 8, 2022 (<https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2022:31:FIN>).
- Fomin, Vladislav V. 2020. "From Boring to Intriguing: Personal Perspective on Making Education About Standardization Appealing to Students." Pp. 31–44 in *Sustainable Development, CSR, Sustainability*.
- Forza, Cipriano. 2002. "Survey Research in Operations Management: A Process-based Perspective." *International Journal of Operations & Production Management* 22(2):152–94. doi: 10.1108/01443570210414310.
- García, Ivan, Carla Pacheco, Andrés León, and Jose A. Calvo-Manzano. 2020. "A Serious Game for Teaching the Fundamentals of ISO/IEC/IEEE 29148 Systems and Software Engineering – Lifecycle Processes – Requirements Engineering at Undergraduate Level." *Computer Standards and Interfaces* 67. doi: 10.1016/j.csi.2019.103377.
- Garza-Reyes, Jose Arturo. 2015. "Lean and Green-a Systematic Review of the State of the Art Literature." *Journal of Cleaner Production* 102:18–29. doi: 10.1016/j.jclepro.2015.04.064.
- Gueorguiev, Tzvetelin, and Irina Kostadinova. 2021. "ISO Standards Do Good: A New Perspective on Sustainable Development Goals." *Proceedings Of the 13th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management* 3(Ic3k 2021):133–37. doi: 10.5220/0010658000003064.
- Heikkilä, Jussi, Timo Ali-Vehmas, and Julius Rissanen. 2021. "Connecting the Dots: A Bibliometric Analysis of the Link Between Standardization and Economic Growth." *EURAS Proceedings 2021: Standardisation and Innovation* 283–302.
- Idowu, Samuel O., Henk J. de Vries, Ivana Mijatovic, and Donggeun Choi. 2020. *Sustainable Development Knowledge and Education About Standardisation*. Springer Nature Switzerland AG 2020.
- IFAN. 2018. *Education and Training about Standardization: Different Needs for Different Roles*.
- Ikram, Muhammad, Qingyu Zhang, Robert Sroufe, and Marcos Ferasso. 2021. "Contribution of Certification Bodies and Sustainability Standards to Sustainable Development Goals: An Integrated Grey Systems Approach." *Sustainable Production and Consumption* 28:326–45. doi: 10.1016/j.spc.2021.05.019.
- ISO. 2014. "Good Practices for Collaboration between National Standards Bodies and Universities." *International Organization for Standardization* 100.
- ISO. 2021. "ISO - Strategy 2030." Retrieved February 16, 2022 (<https://www.iso.org/strategy2030.html>).
- ISO. n.d. "Repository of Teaching Materials." Retrieved June 25, 2021 (https://www.iso.org/sites/materials/teaching-materials/education_materials-higher-edu.html).
- Jachia, Lorenza, Serguei Kouzmine, and Haiying Xu. 2020. "UNECE Initiatives on Education on Standardization." Pp. 139–59 in *Sustainable Development Knowledge and Education About Standardisation*.

- JSA. n.d. "Standardization Educational Materials - Japanese Standards Association (JSA)." Retrieved February 3, 2022 (https://www.jsa.or.jp/jsa/jsa_edu_index).
- van de Kaa, Geerten. 2020. "Mutual Enforcement of Research and Education—The Case of Structured Inquiry-Based Teaching of Standardization." Pp. 45–55 in.
- Kanevskaia, Olia. 2020. "The Need for Multi-Disciplinary Education About Standardization." Pp. 161–78 in *Sustainable Development Knowledge and Education About Standardisation*.
- Katusic, Damjan, Pavle Skocir, Mario Kusek, Gordan Jezic, Carlo Ratti, and Iva Bojic. 2017. "Hands-On Education about Standardization: Is That What Industry Expects?" *IEEE Communications Magazine* 55(5):133–44. doi: 10.1109/MCOM.2017.1601134.
- Mijatovic, Ivana. 2020. "Teaching Standardization to Generation Z-Learning Outcomes Define Teaching Methods." Pp. 191–208 in *Sustainable Development, CSR, Sustainability*.
- Pohle, Anna, Knut Blind, and Dmitry Neustroev. 2018. "The Impact of International Management Standards on Academic Research." *Sustainability (Switzerland)* 10(12):1–19. doi: 10.3390/su10124656.
- Potoski, Matthew, and Aseem Prakash. 2009. "Information Asymmetries as Trade Barriers: ISO 9000 Increases International Commerce." *Journal of Policy Analysis and Management* 28(2):221–38.
- Puiu, Silvia. 2020. "Strategies on Education About Standardization in Romania." Pp. 95–110 in.
- Serhan, Hiam, and David Nahon. 2021. "The Role of Management System Standards for Sustainability Business Models and Ecosystemic Innovation." *EURAS Proceedings 2021: Standardisation and Innovation* 521–39.
- UN. 2015. "Transforming Our World: The 2030 Agenda for Sustainable Development." *General Assembly*. doi: 10.1163/157180910X12665776638740.
- UNECE. n.d. "START-Ed Group on Education and Standardization | UNECE." Retrieved May 21, 2021 (<https://unece.org/trade/wp6/groups/start-ed>).
- UNIGE. n.d. "Sustainable Societies and Social Change - Faculté Des Sciences de La Société - UNIGE." Retrieved March 27, 2022 (<https://www.unige.ch/sciences-societe/formations/masters-in-english/socialchange/>).
- Vasileva, Elka. 2020. "Education About Standardization in the Context of Sustainable Development." Pp. 79–94 in *Sustainable Development Knowledge and Education About Standardisation*.
- de Vries, Henk. 1997. "Standardization – What's in a Name? Terminology." *International Journal of Theoretical and Applied Issues in Specialized Communication*, Vol. 4, No. 1, Pp. 55–83. <https://dx.doi.org/10.1075/Term.4.1.05vri>. (Rectification in Vol. 4, No. 2, p. 198).
- de Vries, Henk J. 2014. "How to Implement Standardization Education in a Country." Pp. 262–76 in *Modern Trends Surrounding Information Technology Standards and Standardization within Organizations*. IGI Global.
- de Vries, Henk J. 2020a. "Addressing Sustainability in Education About Standardisation—Lessons from the Rotterdam School of Management, Erasmus University." Pp. 57–75 in *Sustainable Development, CSR, Sustainability*.
- de Vries, Henk J. 2020b. "Sustainable Development: Knowledge and Education About Standardisation—Discussion." Pp. 211–14 in *Sustainable Development Knowledge and Education About Standardisation*.
- de Vries, Henk J. 2021. "Meeting COVID-19 Rules - A Multiple Case Study of Standardization and Innovation in the Cultural Sector." *EURAS Proceedings 2021: Standardisation and Innovation* 155–70.
- de Vries, Henk J., and Tineke M. Egyedi. 2007. "Education about Standardization: Recent Findings." *International Journal of IT Standards and Standardization Research* 5(2):1–16. doi:

10.4018/jitsr.2007070101.

- de Vries, Henk J., Jeroen Trietsch, and Paul M. Wiegmann. 2020. "Learning in Communities of Standardisation Professionals." Pp. 179–89 in *Sustainable Development Knowledge and Education About Standardisation*.
- Walshe, Ray, Kevin Casey, Jane Kernan, and Donal Fitzpatrick. 2020. "AI and Big Data Standardization: Contributing to United Nations Sustainable Development Goals." *Journal of ICT Standardization* 8(2):77–106. doi: 10.13052/jicts2245-800X.821.
- Wright, Laurence A., Julie Sinistore, Mike Levy, and Bill Flanagan. 2020. "Standards in the Classroom: A Vehicle for Sustainability Education." Pp. 3–16 in.
- Zhao, Xiaoli, Pavel Castka, and Cory Searcy. 2020. "ISO Standards: A Platform for Achieving Sustainable Development Goal 2." *Sustainability (Switzerland)* 12(22):1–19. doi: 10.3390/su12229332.

APPENDICES

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* ⁷ (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

Table 5 – Opportunities to promote EaS

●
⁷ SDOs* = Regional SDOs, IEC, UNECE, and IFAN

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* ⁸	SDOs** ⁹
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

●
⁸ NSBs* = National Standards Bodies OR SDOs at the national level.
⁹ SDOs** = Regional and International SDOs

Create a formal EaaS 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?
- 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 5 – The 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”

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?

APPENDIX D: ISO EDUCATION STRATEGY PROPOSAL

Abstract: **[Problematic]** Standardization is essential for business and society. However, many people are unaware of this and lack knowledge. This issue has been investigated for a few decades, and several institutions have taken the initiative to contribute to having more Education about Standardization (EaS) worldwide, including ISO and its members. Despite these efforts, the issue persists. **[Purpose]** The ISO/CS Research and Innovation unit investigated potential projects that ISO could develop to assist its members in fostering Education about Standardization in their countries. **[Methodology]** After a comprehensive literature review, the data was collected in three steps: in-depth interviews with university professors and regional Standard Development Organizations (SDOs); a survey with national standards bodies (NSBs); and in-depth interviews with NSB representatives. An open-access academic article and the Education Strategy were elaborated based on the data collected. **[Findings]** The NSBs are the organizations that should take the lead at the national level to promote EaS. However, they significantly differ in where they are in terms of EaS. The article clarifies the need for EaS, what should be achieved in the field in the following years, potential solutions to reach the objectives and how to operationalize them, the future of EaS, and the role of key stakeholders – including ISO and its members. **[Practical implications]**. The article advances knowledge in the field of EaS, with a focus on the role and actions of SDOs and provides suggestions on how stakeholders can work together to foster EaS. The education strategy proposes projects that ISO should develop in the next years to support its members in fostering EaS in their countries effectively. **[Originality/value]** The article is one of the first studies focusing on providing strategies for EaS worldwide, while the strategy details what ISO should do.

Ninety NSBs participated in the survey, and ten of them were interviewed. During the individual meetings, the interviewees provided constructive feedback and helped to determine the best support that ISO could possibly offer to the NSBs to succeed in promoting EaS in their national context. All feedback was taken into consideration. Highlights on the Strategy's overall structure were:

The significance of formulating ISO Education Strategy

- NSBs were delighted to see that ISO has formulated the education strategy to raise EaS to an unprecedented height. In addition, they see this action as an essential and inspiring event for all member states, institutions and related workers that carry out EaS.
- They recognized the Strategy's strategic relevance for promoting the implementation of the ISO Strategy 2030 and goals 'standards used everywhere' and 'advance inclusivity and diversity of the ISO system'.
- The members hope to strengthen the exchange and cooperation on EaS with ISO by promoting EaS in their countries while assisting the implementation of the ISO Education Strategy.
- They believe that the Strategy is comprehensive in content, clear in thinking, and flexible in employability.
- All NSBs interviewed are open and available to provide further assistance and collaborate with the Strategy. All NSBs that participated in the survey have provided a contact for further exchange in EaS matters.


The rationale of the projects proposed:

- In total, six projects are proposed. The projects to be executed in the first year are the "EaS maturity model", to access what is the EaS stage in a given country, the "EaS Network", to allow exchange and provision of materials within researchers

and NSBs, and the “EaS materials’ repository”, which will provide assistance with translations, distribution, and update of the materials delivered in the EaS Network and by ISO members. These projects will offer support to each other and serve as a foundation for the following years’ projects.

- Year two projects are the “EaS webinars and workshops” and “EaS research projects”. Based on the EaS maturity model findings, support from the Network and materials available, these projects aim to promote EaS to specific target groups, such as professors, by promoting public events and incentives for conducting research.
- Finally, the “EaS international joint conference” will foster exchange between NSBs and the academic community while raising the visibility of standards, standardization, and ISO.

The ISO Education Strategy is available below (non-confidential version).

	
<h2 style="text-align: center;">ISO Education Strategy</h2>	
PROGRAMME MANAGER	STRATEGIC PRIORITIES P1.1 DEMONSTRATE THE BENEFITS OF STANDARDS P3.2 ADVANCE INCLUSIVITY AND DIVERSITY IN THE ISO SYSTEM
SUMMARY <ul style="list-style-type: none"> • The ISO/CS R&I unit recognizes the importance of Education about Standardization (EaS). The ISO Education Strategy resulted from research based on academic theory and interviews with professors, ISO members, and international and regional Standard Development Organizations. The ISO Education Strategy compiles the best-possible projects that ISO could carry out to foster EaS worldwide. • ISO will support the members throughout these projects to develop EaS activities in their countries. ISO will <u>not</u> develop programs for individual countries or reach local stakeholders without prior consent from the local member. • ISO will execute the projects with the support of its members and other stakeholders through partnerships. 	
TIMELINE <ul style="list-style-type: none"> • Project deliverables expected per year: <ul style="list-style-type: none"> ○ Year 1: EaS materials’ repository; EaS Network; EaS maturity model. ○ Year 2: EaS webinars and workshops; EaS research projects. ○ Year 3: EaS international joint conference. 	
DESIRED OUTCOME(S) <ul style="list-style-type: none"> • Enable ISO members to promote Education about Standardization at all educational levels and raise people’s awareness about the relevance of standards and standardization. • Increase the number of young professionals effectively creating and applying standards to address real-world issues. • Consolidate standardization as an academic discipline. • Encourage Education about Standardization at national and international levels. • Strengthen partnerships with our members, IEC, regional and sub-regional Standards Development Organizations. 	
EXPECTED BENEFIT(S) <ul style="list-style-type: none"> • Standards used everywhere. <ul style="list-style-type: none"> ○ Increase the national and international relevance of ISO and NSBs. ○ Increase the number of standards users. • Advance inclusivity and diversity in the ISO system. <ul style="list-style-type: none"> ○ Increase the participation of the next generation in standardization. • Demonstrate the benefits of standards and all voices heard. <ul style="list-style-type: none"> ○ Make students from all countries aware of standards, the standardization system, and how these benefits society. 	

<ul style="list-style-type: none"> ○ Make people from all areas, in particular from humanities, aware of standards and standardization's importance. 	
DEFINING SUCCESS (IN SCOPE) <ul style="list-style-type: none"> • We are able to effectively foster Education about Standardization by supporting our member's activities related to education at the national level. • We are able to: <ul style="list-style-type: none"> ○ Create a meaningful materials' repository. ○ Create a network of researchers and NSBs to share the best EaS practices and materials. ○ Understand our members' needs (EaS maturity model). ○ Promote EaS through webinars, conferences, and research. • We develop projects in collaboration with our key partners, such as IEC and other international and regional Standards Development Organizations. • Professors at all educational levels, particularly at universities, start to teach about standards more actively and efficiently. • Universities and research centres develop more research about standards and standardization, leveraging the actions started by the ISO Education Strategy. • Students and young professionals make more use of standards to solve problems and find solutions for real-world issues (e.g., addressing the SDGs). 	
DEFINING SUCCESS (OUT OF SCOPE) <ul style="list-style-type: none"> • Academics are part of the standardization system – professors participate in the TCs. • Academics and young professionals feel empowered on taking more responsibilities in the ISO system. 	
PROJECT EaS materials' repository	OUTPUT(S) <u>Teaching material's repository</u> <ul style="list-style-type: none"> • A central online teaching and learning materials' repository organized by subject area, target audience, SDGs addressed, etc. • Provide a toolkit of materials for academia as part of the World Standards Cooperation (WSC) partnership with IEC and ITU. • Materials include success stories (case studies), videos, PowerPoints, textbooks, serious games, etc. • Materials should be translated to the official ISO languages. <u>ISO Education Strategy webpage</u> <ul style="list-style-type: none"> • The web page reunites materials at the different educational levels and the initiatives related to EaS worldwide. <u>Teaching standards booklet</u> <ul style="list-style-type: none"> • Revamp or the booklet "Teaching Standards: Good practices for collaboration between National Standards Bodies and universities." • Include the "Masters of Arts in Standardization, Social Regulation and Sustainable development" from the University of Geneva as a case study (lessons learned). • The booklet includes the EaS maturity model findings, the EaS best practices and the links of standardization and the SDGs. • All NSBs should be invited to include case studies, share best practices, and provide feedback in the booklet through the members' monthly meetings. REQUIREMENTS FROM PARTICIPANT MEMBERS <ul style="list-style-type: none"> • Provide materials to the repository. • Provide yearly updates of the materials provided
PROJECT EaS Network	OUTPUT(S) <ul style="list-style-type: none"> • Create and support a network of people interested in EaS to share projects and exchange ideas and best practices. These stakeholders will complete the repository and be an essential element of other EaS-related projects. • ISO/CS R&I unit participation in internationally relevant conferences related to EaS. • Development of content on adequate platforms to attract young people (e.g., TikTok) (potential partnership with the ISO/CS Comms). • It is recommended that under the framework of the World Standards Cooperation (WSC), IEC, ISO, and ITU establish a Task Force (TF) to promote the orderly development of global EaS. OUTCOME(S) <ul style="list-style-type: none"> • Facilitate exchanges between NSBs, professors, and other stakeholders. • Expand the directory of specialists (professors, TC members, etc.) that provide services related to EaS (e.g., providing courses) to ISO's community. REQUIREMENTS FROM PARTICIPANT MEMBERS <ul style="list-style-type: none"> • Indicate one or two academic participants from their country. • Actively participate in the Network by exchanging information and materials.
PROJECT	OUTPUT(S) <ul style="list-style-type: none"> • Create the "EaS Maturity Model". The model is a tool to measure the member's development in terms of EaS at the national level.

EaS maturity model	<ul style="list-style-type: none"> The model will help the ISO/CS R&I unit to suggest best practices to members individually or in clusters to develop EaS at the national level. To provide a detailed report that classifies the member's countries while considering ministries of education positioning and different educational models. <p>OBSERVATIONS</p> <ul style="list-style-type: none"> A mix of maturity models for businesses will be used to create the model to access the EaS level in a given country.
<p>PROJECT</p> <p>EaS webinars and workshops</p>	<p>OUTPUT(S)</p> <ul style="list-style-type: none"> Public events to raise awareness of different audiences A dedicated workshop in the ISO week (success stories from members).
<p>PROJECT</p> <p>EaS research projects</p>	<p>OUTPUT(S)</p> <p><u>EaS annual research prizes for students</u></p> <ul style="list-style-type: none"> ISO provides data and guidance to students to develop academic works (e.g., Master thesis) on standardization. Prizes consist of financial awards and a certificate. EaS research should focus on priority topics for academia <ul style="list-style-type: none"> Standards as a tool to address the Sustainable Development Goals (SDGs). Standardization and climate change. Societal impacts of standardization. Identifying the best practices for developing EaS at the national level. Identifying the best practices for including EaS into the academic curricula. Mapping the EaS at schools and universities worldwide.
<p>PROJECT</p> <p>EaS international joint conference</p>	<p>OUTPUT(S)</p> <ul style="list-style-type: none"> Hold an international conference with the objective to promote education in the field of standardization. Core themes should be EaS associated with economic development, sustainable development, and gender equality. Additional topics should focus on areas currently underexplored by researchers, such as standards and social sciences. Enhance the visibility of other ISO/CS R&I unit EaS projects. <p>OBSERVATIONS</p> <ul style="list-style-type: none"> Target audience and participants: SDOs, researchers, professors, universities, and students – worldwide.