Journal of Cleaner Production 311 (2021) 127489

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Social sciences and humanities in the education of civil engineers: Current status and proposal of guidelines

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ARTICLE INFO

Handling editor: Cecilia Maria Villas Bôas de Almeida

ABSTRACT

Apart from the importance of Social Sciences and Humanities (SSH) in and of themselves, the potential contribution that they can make to Science, Technology, Engineering and Mathematics (STEM) is huge. Even though some STEM fields have already incorporated SSH elements in their research and education, there are still other disciplines that have not yet approach the intersection between them and SSH. Among these is civil engineering (CE), which has traditionally been set as purely technological and has lacked the inclusion of SSH elements in it. Nonetheless, it is indispensable that engineers have knowledge in SSH to allow them to make decisions more perceptively, realistically and critically. Ultimately, this social understanding can lead them to design and plan solutions that are more socially sustainable. However, there are still no clear guidelines on how to include aspects from social sciences and humanities at the higher education level. This article analyses perceptions, the real status and possible barriers for the incorporation of SSH in the studies of CE. Besides, it analyses and discusses the different methodologies in which engineering students can be introduced to these topics. A triangulation method that combined the use of qualitative and quantitative data was used. Surveys to students, researchers, professors and practitioners were carried out (n=583). Besides, accreditation criteria and CE syllabuses of 100 faculties were reviewed. The analyses showed a dissent between individual perceptions, collective reality and legislative frameworks. Even though the survey responses showed a common agreement concerning the inclusion of SSH, only a minority of CE schools have introduced SSH in their curricula. Besides, accrediting bodies have not yet introduced this as a specific requirement in their criteria. The barriers detected in the incorporation of SSH in CE curricula were: (1) resistance to change, (2) external influences on the curricula, (3) lack of guidelines, (4) misconceptions on what SSH in relation to CE involves. It is necessary to gradually incorporate both hard social skills and soft skills from the beginning of the degree courses and to do so in a transversal way in most of the subjects if professionals and researchers that are capable of designing socially sustainable activities are needed.

1. Introduction

Social sciences and humanities (SSH) comprise a heterogeneous set of academic disciplines that help provide answers and reflect on various dimensions of society and human behaviour. Research in SSH is fundamental, as it can stimulate formulation of new questions that require urgent consideration and engagement (Pickersgill et al., 2018). Notwithstanding the relevance of SSH, there have been noticeable discrepancies over the years between their potential importance and the comparatively scant attention they have received from other research and education communities (Pohoryles and Schadauer, 2009).

First, regarding research, investigation in SSH has traditionally suffered from several drawbacks compared to research in Science, Technology, Engineering and Mathematics (STEM). Some of these disadvantages involve the misconception that STEM research produces more useful outputs than SSH research (Olmos-Peñuela et al., 2014) and the fact that STEM's research performance and disseminating methods differ from SSH (Larivière et al., 2013; Nederhof, 2006; Holzman, 2016).

In the last decade, however, the importance and usefulness of SSH have been increasingly acknowledged. Even though some authors had previously detected a lack of funding for interdisciplinary projects (Overland and Sovacool, 2020), Sonetti et al., (2020) examined the shift in allocation of research project funding from STEM-centred to requiring an approach that combines SSH and STEM. Within Europe, the European

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https://doi.org/10.1016/j.jclepro.2021.127489
Received 11 February 2020; Received in revised form 21 April 2021; Accepted 10 May 2021
Available online 21 May 2021

Commission had specific calls in Horizon (2020) for projects that required inclusion of SSH research (European Commission 2011, 2017).

Apart from the inherent importance of SSH themselves, the range of potential contributions that they can make to STEM is large (Rochlin, 2014). This is partly due to the fact that modern societies have undergone profound changes over the last few decades that demand a more interdisciplinary approach to problems (Birr and Layton, 1975; Douglas, 2012; Sørensen, 2009). As Spelt et al. (2017) emphasise, interdisciplinary knowledge for STEM researchers and practitioners is essential when it comes to analysing and solving complex social problems since it can help them find solutions more critically and perceptively.

Undoubtedly, views on the SSH-STEM relationship are diverse and the matter has spurred various debates in a number of areas. Nevertheless, there are many areas in which integrating SSH in STEM can be beneficial. Examples might include SSH support to STEM policymaking processes (Katsikides, 1998); development of technology and infrastructure that is sustainable in all dimensions (Sovacool et al., 2015); analysis of possible responses or adaptations to such technologies at different levels, ranging from an individual to a policy level (Bechtold et al., 2017a, 2017b, 2017b; Decker et al., 2017; Mormina, 2019); examination of the ethical questions embedded in research processes (Eggleson and Berry, 2015); or consideration of responsible research and innovation systems in STEM that tackle SSH challenges throughout the world (Glerup and Horst, 2014, Timmermans et al., 2020). Some STEM fields have already witnessed a paradigm shift in which SSH have progressively become more important. This is the case, for instance, of research in the energy-SSH, (Rochlin, 2014; Sovacool, 2014; Sovacool et al., 2015; Ingeborgrud et al., 2020; Sonetti et al., 2020), climate change-SSH (Palsson et al., 2013; Overland and Sovacool, 2020), or nanotechnology-SSH (Sweeney, 2006; Krabbenborg, 2016) intersections.

Apart from research, it is also relevant to consider the intersection of SSH and STEM in Higher Education (HE). Notwithstanding the importance of SSH in STEM education, at present, some STEM programmes are failing to address some of the challenges emerging in modern societies. According to Lang et al. (1999), engineering education at universities has not changed appreciably for decades, even though the need for curriculum reform has been acknowledged. This idleness among higher level institutions contrasts with the speed of change throughout the world, driven by rapidly evolving factors such as climate change or globalisation, which have wide-ranging impacts on the economy, culture and society.

In fact, there have been a few studies in the last two decades on including SSH in STEM educational programmes. Back in 1982, Turmeau analysed how engineering degrees at that time had to adapt to the context of a changing society by broadening their curricula to ensure that positions were available for students outside very narrow technological positions (Turmeau, 1982). Along a similar line, Fincham and Roslender (1988) discussed the need for implementing socio-technical system methodologies when educating engineers. The report released by the Global University Network for Innovation (GUNI, 2019) emphasised the need for HE to create synergies between science, technology and humanities. It also explored practices at institutions around the world that are introducing interdisciplinary principles into their education models. Some areas that have already been emphasised in this regard are education in ethics (Wang and Thomspon, 2013; Sunderland et al., 2014) and sustainability (Lozano and William, 2013; Thürer et al., 2018). Other studies in the same vein can be found in Litchfield et al. (2016), Berdanier et al. (2018), Galvão et al. (2019) or Mazzurco and Daniel (2019).

Despite the efforts that have already been made, there is still no global agreement on the systematic inclusion of SSH in STEM university programmes. In this context, it is relevant to examine the dearth of research on integrating SSH in such programmes. In some fields like medicine (Joo, 2016; Liasidou and Mvarou, 2017), energy (Stankiewicz, 2019) or the environment (Leroy et al., 2001; Zoller, 2013), SSH are becoming progressively important in educational programmes. Nonetheless, this is not the case for some fields that are still in their infancy in terms of systematically integrating SSH. In particular, civil engineering (CE) can be considered as one of the STEM fields which has yet to find an answer to this shortcoming in current teaching practices.

However, the potential contribution that SSH can make to CE is huge (Josa and Aguado, 2019). In fact, the Royal Charter of the first professional institution of civil engineers (the Institution of Civil Engineers, ICE) formally defines the profession of civil engineering as "being the art of directing the great sources of power in Nature for the use and convenience of man (…)". Such a definition illustrates the connections between technology ("the art of directing the power of nature"), environment ("nature") and society ("man"). This emphasises the need to include SSH in civil engineering education, which has also been formally acknowledged by several civil engineering institutions. For instance, the 2025 vision for CE from the American Society of Civil Engineers revolves around quality of life, ethics, and sustainability and encourages education programmes to incorporate such elements (ASCE, 2007); a recent report by ICE focuses on ways in which infrastructure can create social value and have positive impacts on community life and the well-being of individuals and families (ICE, 2020).

To the best of the authors' knowledge, despite the enormous impacts that infrastructures have on society, and the increasing acknowledgement of the need to include SSH in both the education and practice arenas of CE, no recent publications exist on SSH education particularly oriented for civil engineers.

In light of the above, the objectives of this paper are threefold. First, the article aims to analyse the current status of SSH in formal HE CE programmes. Three major studies are presented for this purpose. Firstly, perceptions regarding SSH from students, researchers and professors at a civil engineering faculty are examined; secondly, an extensive analysis of 100 universities is carried out, examining the way in which they include social aspects in their curricula; thirdly, a review of accreditations and agreements that consider the incorporation of SSH in CE is presented. Second, the paper also aims to propose general and effective educational methodologies in which civil engineering students can be introduced to social topics as well as fundamental topics that should be incorporated into civil engineering programmes. Thirdly, this paper aims to contribute to the discussion on the need to include SSH in STEM and, in particular in CE. For this, replies to the surveys from current students, researchers and professors are contrasted against answers given by CE practitioners.

The paper is structured as follows: Section 2 describes the general conceptual framework for this study. Section 3 presents the methodology that has been followed to develop the analysis. Next, section 4 provides an overview of the current status of topics related to SSH in CE programmes. This includes an examination of current educational frameworks and agreements, analysis of inclusion of SSH at a global level and the investigation of perceptions from the field of CE towards the inclusion of SSH. Then, based on the results from the previous section, section 5 examines the most critical aspects as well as different methodologies to introduce engineering students to SSH topics. Finally, section 6 provides a conclusion.

2. Conceptual framework

The overarching framework within which the present study lies is interdisciplinarity in HE. This section reviews concepts and debates that are closely linked to the article's objectives. This includes discussions on the definition and benefits of interdisciplinarity and how this applies to the HE context. Interdisciplinarity in HE can have multiple facets, depending on whether it characterises research or teaching and learning. Hence, the case for interdisciplinarity when dealing with the intersection between SSH and STEM is reviewed first for research, and then for teaching and learning. Finally, literature concerning SSH and CE is examined. This study falls in this area, as shown in Fig. 1.

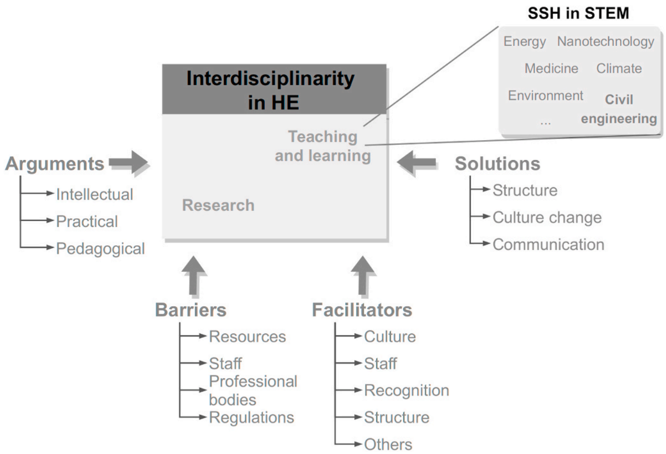

Fig. 1. Overarching framework of the study.

Note that the information presented in this section is not intended to be exhaustive, but to address major information related to the topic being analysed to provide a basis to improve understanding of the article. In this paper, *Higher Education* is understood as the primary knowledge creation system of society (Ison, 1999). Said system connects research with teaching and learning. Secondly, *SSH* are understood as the fields that study human behaviour and interactions in different contexts, such as social, cultural, environmental, economic and political. Evans et al., (2007) observe that "the humanities include subjects such as art, history and literature while social science includes subjects such as economics, political science, sociology and psychology." Thirdly, *STEM* is understood as Science, Technology, Engineering, and Mathematics. It has begun to be promoted in education to enhance the STEM workforce and address the major challenges at present (Bybee, 2010).

2.1. Interdisciplinarity in HE

There has been a growing number of studies on interdisciplinarity over the last decades. In the education context, Ashby and Exter (2019) see interdisciplinarity as the integration of knowledge drawn from diverse disciplines to address problems that cannot be solved by one discipline. In the literature, authors have classified interdisciplinarity into different degrees, ranging across intradisciplinarity, multidisciplinarity, crossdisciplinarity, and transdisciplinarity (Griffin et al., 2006). However, some authors have contested such division, arguing that interdisciplinarity is a further level in this classification (Jensenius, 2012; Jaeger, 2018). The reader can find a review of the definitions and application of interdisciplinarity in the HE context in Chettiparamb (2007).

Given the central role of HE in interdisciplinary knowledge creation and dissemination, Power and Handley (2017) developed a best-practice model for integrating interdisciplinarity in HE. They grouped their results in four main areas which are arguments given for the need for interdisciplinarity in HE, barriers, facilitators, and respective solutions.

First, regarding arguments, several authors centre the need for an interdisciplinary approach in HE around the fact that in today's world, most of challenges are complex, and their solution requires a perspective that transcends traditional disciplinary borders (Donina et al., 2017; Power and Handley, 2017; Ashby and Exter, 2019; Van den Beemt et al., 2020). Stember (1991) suggested three arguments for interdisciplinarity: intellectual, practical and pedagogical.

Basu (2017) highlighted the potential of interdisciplinarity for teaching knowledge and skills beyond students' disciplinary silos, developing an interest for other disciplines, integrating and examining problems from different perspectives, and learning to develop innovative solutions to complex problems. Besides, interdisciplinarity in teaching and learning can have significant benefits such as on graduate employability, problem-solving, communication or teamwork skills (Nissani, 1997; Newell, 1994; Jones, 2010; Marcketti and Karpova, 2014; Power and Handley, 2017). Leal Filho et al. (2021) reviewed the competences related to sustainability required by teaching staff and practitioners from literature, and their work shows how this is often linked to interdisciplinary thinking.

Secondly, barriers to interdisciplinarity in HE are identified by Power and Handley (2017) as a lack of resources, such as time, or space; resistance to change from the staff; and the rigidity of regulations from academia and professional bodies. These issues are also reported by other authors, such as Nissani (1997), Foster (1999), Jones et al., (2010), and Bryant et al., (2014).

Thirdly, some of the facilitators for integrating interdisciplinarity that Power and Handley (2017) detected in HE are incentives, staff mentality, new HE institutional structures, personal values, and physical proximity between disciplines in an HE institution. Other researchers also report these factors. For instance, Mullins (2007) and Torrington et al., (2014) acknowledged individual recognition and effective talent management as key for interdisciplinary work in HE.

Finally, Power and Handley (2017) detect three interrelated solutions for better integration of interdisciplinarity in HE: better communication, an adequate structure and a cultural change. In fact, the need for a cultural shift in HE has been recognised by several authors (Kezar and Eckel, 2002; Barlett, 2008; Annan-Diab and Molinari, 2017). Lazzarini et al., (2018) emphasise the importance of the role of academics as agents of change. Even though they can lead to transformations, Lazzarini et al., (2018) argue that they could be more engaged in leading efforts to implement changes in HE programmes.

2.2. SSH and STEM

One specific area within the broad context of interdisciplinarity in HE is the intersection between SSH and STEM. This has led to interdisciplinary research and educational research. While the former is concerned with research projects with an interdisciplinary component, the latter is concerned with how best to introduce interdisciplinarity in teaching and learning. This is examined in the following two subsections.

2.2.1. Research

Okamura (2019) presented empirical evidence of the positive influence from interdisciplinarity on research performance by examining clusters of highly cited papers from different disciplines. Nonetheless, studies that look at the intersection between SSH and STEM from such a broad perspective are scarce. In general, researchers have analysed the relationships between SSH and a specific STEM field. Some of the areas that have been studied include climate (Von Storch and Stehr, 1997; Leyshon, 2014; Kuster and Grey, 2017, Tłokiński, 2020) energy (Mallaband et al., 2017; Bavaresco et al., 2020), medicine (Smith and Grigsby, 2017; Timmermans and Tietbohl, 2018), and nanotechnology (Ebbesen, 2008; Zalewska-Kurek, 2016; Berube et al., 2020).

Some authors have examined the barriers that hinder interdisciplinary research between SSH and STEM. Schuitema and Sintov (2017) identified challenges and obstacles for interdisciplinary research in the context of SSH and energy. According to their results, these barriers are insufficient knowledge and skills, limited and unequal distribution of funding, funding evaluation criteria, publication processes and academic promotion processes favouring disciplinary research, and a lack of HE institutional systems for interdisciplinarity. Apart from these issues, Rekers and Hansen (2015) examined these barriers from a geographical perspective which, they argue, adds to other barriers for facilitation of interdisciplinary research.

2.2.2. Teaching and learning

Research regarding teaching and learning in HE at the intersection between SSH and STEM can frequently be found in the context of sustainability, in what is referred to as Education for Sustainable Development (ESD). Some of the studies developed so far focus on sustainability integration in STEM programmes (Feinstein and Kirchgasler, 2015; Zizka et al., 2021). Because of the nature of sustainability issues, this usually implicitly encompasses interdisciplinarity. As Newell 1994 and Spelt et al., (2017) put it, SSH are embedded in the context of interdisciplinary thinking. For instance, Leal Filho et al. (2021) regarded social responsibility, ethics, and cultural diversity as essential competences for staff teaching sustainability, and Correa et al., (2020) highlighted the importance of including social sustainability elements in undergraduate programmes.

Several authors have reported academic experiences of sustainability or SSH integration within STEM courses. Tasdemir and Gazo (2020) analysed how sustainability could be integrated into a specific course within a STEM department. Hergert et al., (2010) reported an academic project in which groups of students from a range of degrees, both SSH and STEM, had to prepare presentations for an interdisciplinary audience.

Besides curricular activities, Lattuca et al., (2017) performed a survey among STEM academia regarding perceptions concerning interdisciplinarity which also included questions on SSH. They found the importance of curricular activities on students' perceptions of interdisciplinarity and the potential of extra-academic activities to develop social skills. In a similar vein, Spelt et al., (2017) surveyed STEM students about their experiences related to the cognitive, emotional and social learning dimensions in HE.

Specific studies on HE curricula dealing with the inclusion of SSH in STEM programmes are scarcer. For instance, Molthan-Hill et al., (2019) examine climate change education and propose a conceptual framework on how HE institutions can deploy said integration in practice. They detected four different ways in which this can be done: specialist approach, piggybacking, mainstreaming, and connecting. In Sochacka et al., 2016, the introduction of Arts in STEM education is seen as a means of enhancing students' creativity. They coined a recent term, STEAM, which adds an A for Arts & Humanities to the original STEM acronym. There are multiple advocates for such an approach (De la Garza, 2019). The TEACHENER project (Stankiewicz, 2019) had the main purpose of enriching energy courses through teaching social sciences, and it supported the development of teaching modules covering topics related to social aspects of energy for educating graduate students. Some of the modules that they included were philosophy and ethics of energy development, the social impact of energy technologies, and conflict management.

2.3. SSH and civil engineering

The importance of SSH in the context of CE has been increasingly acknowledged over the years (Sørensen, 2009; Sierra et al., 2018; Josa and Aguado, 2019). Nonetheless, specific studies on the intersection of SSH and CE in the HE context are still scarce. Over the years, a few authors have written about the importance of the existing connections between the two fields.

In 1995, Stokes emphasised the importance of civil engineers receiving formal training on planning, arguing that students need to learn to solve societal and global problems. Russell and Stouffer (2005) analysed CE curricula in the United States and concluded that technically the curriculum was highly specialised in most institutions, although it lacked a focus on different SSH areas. Furthermore, in the context of the United States, Evans et al., (2007) explored the role that SSH played in the CE body of knowledge. They argued that SSH are fundamental to develop CE students' critical thinking skills, improve their skills to communicate with non-engineers, and find and implement solutions to the complex problems that the world is currently facing. Evans and Lynch (2008) further analysed the new body of CE knowledge, and emphasised the importance of SSH, together with Mathematics and Natural Sciences, in CE education. Apart from these technical skills, other authors have analysed and recognised the importance of training civil engineers on cross-cultural communication (Soibelman et al., 2011, Handford et al., 2019).

3. Methods

This paper follows a mixed-method approach. Integrating quantitative and qualitative data leads to an understanding of the current global situation that is both broad and deep. In particular, the method known as triangulation has been employed to examine the study subject from different perspectives. This analysis performs the triangulation at different levels by considering the approaches by Denzin (1978) and Smith (1975). First, it combines both qualitative and quantitative analyses. Second, it considers information from an individual and a collective perspective. Third, the data collection strategy varies, and includes both field analysis (through surveys) and bibliographic research.

At this point, it should be mentioned that, when analysing inclusion of SSH in CE programmes, a distinction is made between skills related to specific technical knowledge on SSH, and transferable skills, which comprise elements such as interpersonal, communication or leadership skills (Dym et al., 2005; Shuman et al., 2005; Gilbuena et al., 2015; Hess et al., 2019). The latter are also referred to as social or transversal skills in the literature.

The framework proposed by Josa and Aguado (2019) was used with regard to specific technical knowledge on SSH. The divisions of SSH used in the framework are based on the UNESCO nomenclature codes, and they helped to consider the various subfields existing within SSH in a consistent and sound manner.

The following subsections present the methods for the three broad analyses that were performed, namely, the survey among different stakeholders in a CE faculty; the analysis of the syllabuses of CE faculties worldwide; and the review of engineering accreditations criteria and recommendations given by engineering education and professional institutions.

3.1. Survey

3.1.1. Survey design

First, an extensive literature review was carried out to design the questionnaire. The field explored for potential survey items was education in civil engineering and the inclusion of social areas. Three questions guided the survey design:

a) To what extent do civil engineering programmes introduce social aspects?
b) Do students, professors and practitioners consider it necessary to include social aspects in civil engineering programmes?
c) What areas within SSH do civil engineering students, professors and practitioners consider to be the most important?

After an initial definition of the items to be included in the survey, the survey was validated. This involved four different groups: a group of 40 students, 4 professors, 2 programme directors and a faculty director, and three civil engineers working in different companies. Their comments on the survey were compiled, and the survey was improved accordingly.

The first part of the survey was designed to define the respondents' profiles. This included information about age, nationality, gender, current occupation, specialisation field (if applicable), and extra-curricular activities. Subsequently, the part related to education comprised three items regarding aspects related to current practices and perceptions on different topics.

Question 1 (Q1) differed for new students, existing students, and professors and researchers. It should be noted that practitioners were not asked Question 1 since it is intended to characterise the expectation and satisfaction of current civil engineering students with respect to their university education. In fact, it should be mentioned that this item only concerns a specific subset of questions from the questionnaire, as the survey also included other questions whose analysis lies outside of the scope of the present article. Questions 2 and 3 (Q2 and Q3) were the same for all stakeholders. The questions are outlined below:

- Q1. New students: "Do you think that the civil engineering degree that you are now starting at university should teach you about any of the following thematic areas?"
  Students: "Do you consider that the university education you have received so far has taught you about the following thematic areas?"
  Professors and researchers: "Do you consider that you include contents related to the following thematic areas in the classes that you teach or in your research activities?"
- Q2. "Do you think that civil engineers should be trained on the social aspects in civil engineering? Choose the most appropriate answer for you."
- Q3. "Following the previous question, which social aspects should be taught to civil engineers?"

The thematic areas that were included in the questionnaire were based on previous frameworks which examined different dimensions of CE related to SSH (UNESCO nomenclature codes, Josa and Aguado, 2019; Stankiewicz, 2019). In particular, the dimensions covered were culture and history, psychology, social communications and relations, socioeconomics, legislation, health and quality of life, politics, ethics and philosophy, arts and aesthetics, and social problems (which includes elements like poverty, development, or inequality).

3.1.2. Sampling

The survey was created using the Survey Monkey tool, and it was circulated both on paper and online. Answers were received between January 20, 2019 and September 5, 2019. The survey was sent out to all stakeholders involved in civil engineering education at the Polytechnic University of Catalonia: undergraduate students, master students, PhD students, researchers and professors. Furthermore, the survey was also sent out to civil engineers working in the same city as the university. In the end, a total of 583 questionnaires were collected. Among these, 16.2% corresponded to first-year students, 21.7% to undergraduate students, 23.3% to master students, 5.3% to PhD students, 16.6% to postdoctoral researchers and professors, and 16.8% to practitioners.

3.1.3. Data analysis

The numerical data collected from all the responses were analysed through descriptive statistics using a combination of Excel and Matlab. The open-ended questions were analysed by examining their contents individually, and the results were clustered into different groups.

3.2. Civil engineering curricula

3.2.1. Analysis design and sampling

CE curricula in universities around the globe were analysed to determine how each institution considers the SSH pillar in their syllabuses. A total of 100 universities were examined. The chosen institutions are in the top one hundred in the QS ranking in the field of Structural and Civil Engineering. The complete list of universities analysed can be found in the Appendix, together with their respective positions in the ranking.

3.2.2. Data analysis

To interpret how social issues are included in the respective civil engineering curricula, six leading indicators were gathered for each undergraduate programme. These indicators are as follows:

- Ranking position and score: the ranking position of each university in the field of Civil and Structural Engineering was compiled. Besides, the scores obtained in the overall index and its indicators (academic reputation, citations per paper, h-index citations and employer reputation) were also gathered.
- Obligatoriness: whether SSH subjects are obligatory or not in the curriculum of the programme.
- Type of subject: whether the SSH subject is a core subject or optional.
- Year(s): academic years during which students take SSH subjects.
- Percentage of credits: the proportion of SSH credits to the total amount of credits.
- Field taught: field of the SSH subject. The framework in Josa and Aguado (2019) was used to classify the different fields.

Apart from the previous indicators, qualitative information was also gathered on the specific contents of the SSH subjects. The course descriptions, objectives and competences were examined whenever such information was available. The framework from Boarin et al., (2020) was adapted to analyse the courses according to their level of focus on SSH. In this framework, they classify subjects as having either a primary, a tangential, a possible, or no focus on sustainability. Because of the complexity of judging whether a subject had a tangential or a possible focus on SSH in some cases, the following three categories were used as part of this research to characterise the different subjects:

- Courses with a primary focus on SSH. Courses that are specifically designed to address issues in the SSH.
- Courses with a possible focus on SSH. Courses in which SSH are not the main focus, but some attention to them is possible. Such attention may differ depending on the professor. For instance, this could comprise a course on sustainability or impact assessment whose focus might only be on environmental aspects or on both environmental and social aspects.
- Courses with no focus on SSH. Courses that do not address any issue within SSH.

The data for each of the previous elements were obtained from the official websites of the universities being analysed. However, 19% of universities studied did not have information available on all the indicators. In these cases, the corresponding university was discarded from the analysis. In the end, a total of 81 programmes from different universities were analysed. These programmes belong to universities in a total of 29 countries located in 5 world regions: Asia, Europe, North America, Oceania, and South America.

3.3. Legal and institutional frameworks

The quality and status of academic programmes may be maintained through their accreditation and assessment. In fact, accrediting models and assessment processes can influence engineering education systems at different levels, namely at internal, external, national, regional, or even international levels (Patil and Codner, 2007). This explains why this paper examined the main accreditation bodies at either national, regional, or international levels. The accreditation criteria were analysed qualitatively. The aspects considered for analysis were the requirement of subjects or contents in areas within SSH as well as consideration of transferable skills (such as teamwork or leadership).

To review existing accreditation systems, apart from searching for specific accreditation systems in different countries, online databases were searched with the keywords "engineering education" and "accreditation". The publications that were found to be useful for this research were Koehn (2001), Gorham et al., (2003), Prados et al., (2005), Patil and Codner (2007), and Agboola and Elinwa (2013). In the end, at an international level, the accreditation bodies that were selected were the Accreditation Board for Engineering and Technology (ABET) and the European Network for Engineering Accreditation (EUR-ACE). At a national level, the bodies examined were Engineers Australia, Engineers Canada, National Board of Accreditation of India, Japan Accreditation Board of Engineering Education, Institute of Engineers Singapore, Accreditation Board for Engineering Education of Korea, Engineering Accreditation Council of Malaysia, and Institute of Engineering Education Taiwan.

Professional and engineering education institutions also play an important role in reflecting the needs of practitioners and making recommendations to shape the engineering studies curricula accordingly. Hence, apart from accreditation criteria, suggestions by two well-known civil engineering professional institutions were considered: the American Society of Civil Engineers (ASCE) and the Institution of Civil Engineers (ICE). As for engineering education institutions, the stances taken by the European Society for Engineering Education (SEFI) and the American Society for Engineering Education (ASEE) were examined.

4. Results: current status of SSH in CE programmes

4.1. Perceptions and current practices

The results of the survey are presented here in three parts. The answers obtained for Q1, Q2 and Q3 are analysed separately. Besides, in each of the questions, the answers given by each stakeholder are shown independently, so it is possible to compare perceptions on the same topic from different groups. The grouping used in the results graphs is: (1) new students, which corresponds to individuals about to start their undergraduate studies in civil engineering; (2) undergraduate students 1, which corresponds to undergraduate students in their first or second years; (3) undergraduate students 2, which corresponds to undergraduate students in their third year or more; (4) master students; (5) PhD students, (6) professors and researchers, and (7) practitioners. With regard to (2) and (3), where deemed necessary and to avoid adding superfluous complexity, the data has been analysed together. With regard to (7), note that they are not included in the case of Q1 for the aforementioned reasons.

First, Fig. 2 shows the results regarding Q1, which is related to current practices carried out at university. In particular, the results are related to the degree to which students perceive that they are trained in SSH topics and the degree to which researchers and professors believe that they incorporate these same SSH topics in their academic activities.

In general, there seems to be an agreement in the majority of the SSH areas. In particular, respondents considered that Psychology, Politics, Ethics and Philosophy, and Arts and Aesthetics are fields that are not given particular emphasis during the studies. Only a total of 4%, 8%, 10%, and 8% respectively considered them to be included in their studies. Around 20% of respondents acknowledged that students are taught in the field of Communications and Social Relations, while around 35% agreed that issues related to Socioeconomics are incorporated. There was more dissent with regard to education in the fields of Culture and History, Legislation and Social Problems. Professors and researchers considered that they incorporate aspects related to Culture and History in their classes and research activities (50%). In contrast, the answers given by both undergraduate and master students were discordant as an average of just 20% perceived this area to be included. As for Legislation, while 50% of all students considered it an area frequently taught during their studies, only 30% of the researchers and professors regarded it as an area that is included. Finally, with respect to Social Problems, only 20% of undergraduate students believed it to be addressed within their studies, whereas more than 35% of master students, PhD students, researchers and professors agreed that they teach and research topics related to this area.

Secondly, Fig. 3 shows the answers to the question of whether SSH should be included in the education of civil engineers. Ultimately, six possible answers were available to respondents. They first had to choose between three main options: Yes, No, or Others. If the answer were affirmative, respondents could choose between four different methods through which SSH should be included in CE studies. The options were: adding SSH subjects in CE studies; adding SSH contents in existing subjects; attending conferences and seminars (not necessarily at university); and finally, learning through professional experience.

In general terms, the proportion of individuals answering each of the options was similar for all the stakeholders. It can be observed that, for all groups, a majority of individuals think that civil engineers should be trained in social aspects. There are, however, some disparities regarding the methodology to be followed to incorporate SSH. Except for PhD students and practitioners, all the stakeholders considered that the best methodology to incorporate SSH in civil engineering education is through addition of SSH content in existing subjects. On the other hand, the answers from PhD students reveal that, for this group, the inclusion of full SSH subjects is perceived as an equally viable method as the addition of SSH contents, because an equal percentage of respondents selected these two options.

Less than 10% of respondents believed that civil engineers should not be trained in social areas but should acquire the corresponding knowledge through professional experience; less than 8% of respondents answered that it is not necessary to train civil engineers in social areas.

Respondents that chose the answer “Others” had to write possible alternatives. Table 1 summarises the main alternatives proposed by respondents from different groups after choosing the “Others” option. A particular aspect to emphasise in relation to the alternative answers given is the existing misconception that SSH are related to the environment. This issue is exposed through answers showing a clear belief that teaching SSH involves areas directly related to climate and pollution.

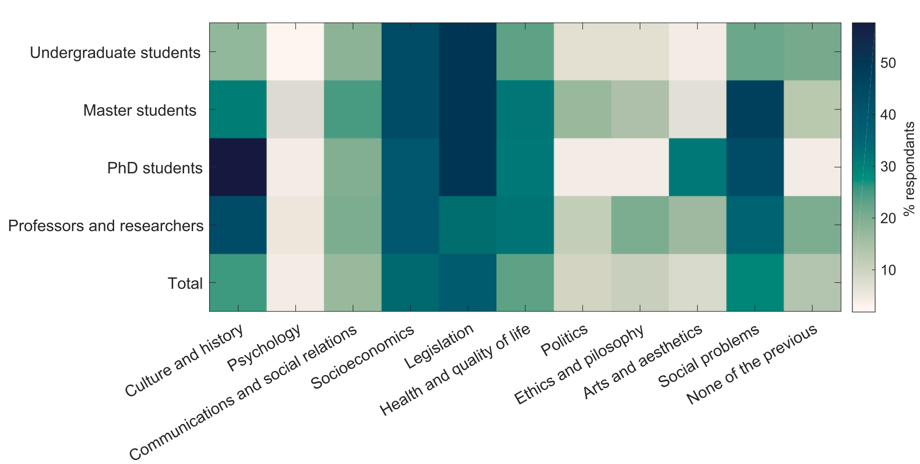

Fig. 2. Answers given to Q1 by each stakeholder.

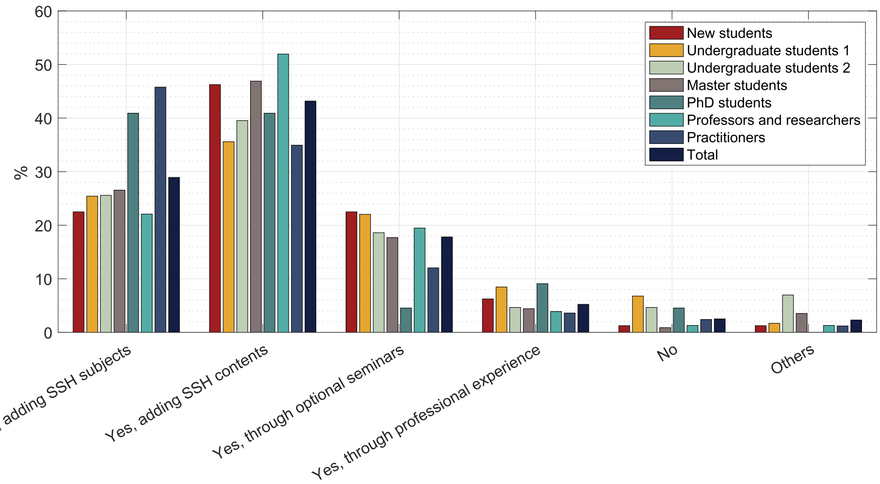

Fig. 3. Answers by interest group to question Q2.

Table 1
Answers given to Q2 with regard to "Others", classified by stakeholder.

Stakeholder	Answer
New students	"Climatic factors"
Students	"All students should be trained, not only engineers (primary school, high school …)"
	"Incorporating a subject of 'Engineering and Society'"
	"Awareness should be created on global pollution; subjects on sustainable construction and environmental aspects should be included"
	"Yes, but I think that social content should be included as an optional subject in the Master. Undergraduate studies should just deal with general civil engineering topics"
Professors and researchers	"The first two answers" (namely, adding SSH subjects and adding SSH contents at the same time)
Practitioners	"Social aspects need to be lived in order to know them well."

Fig. 4 shows the answers given by the different stakeholders to question Q3, which relates to the social aspects they consider should be taught to civil engineers. It can be observed that a low percentage of respondents answered, "None of the previous" and "Others". Concerning the latter, the answers included can be seen in Table 2. The three areas that students and researchers and professors consider essential to include in civil engineering education are Social Problems (59%), Health and quality of life (55%), and Socioeconomics (54%). On the contrary, the areas that were considered essential for the lowest proportion of respondents are Politics (25%), Arts and Aesthetics (21%), and Psychology (13%).

Table 2
Answers given to Q3 with regard to "Others", classified by stakeholder.

Stakeholder	Answer
New students	"Environment" (answered twice)
Students	"Environmental integration and sustainability"
	"Relationship between global warming and construction"
Professors and researchers	"Financing of public works investments"
	"Gender"

Among practitioners, the areas considered to be most important were communications and social relations, socioeconomics, health and quality of life, and social problems. On the contrary, the area that was considered of least importance by practitioners was politics.

Again, the answer given to "Others" showed a misinterpretation of what SSH represent within CE, as students believe that they are directly related to environmental issues.

4.2. Worldwide civil engineering education

Having analysed the curricula as described in section 2.2, the findings are shown as a graph in Fig. 5. Unless stated otherwise, the subjects considered are the ones with a primary focus on SSH. The figure gathers

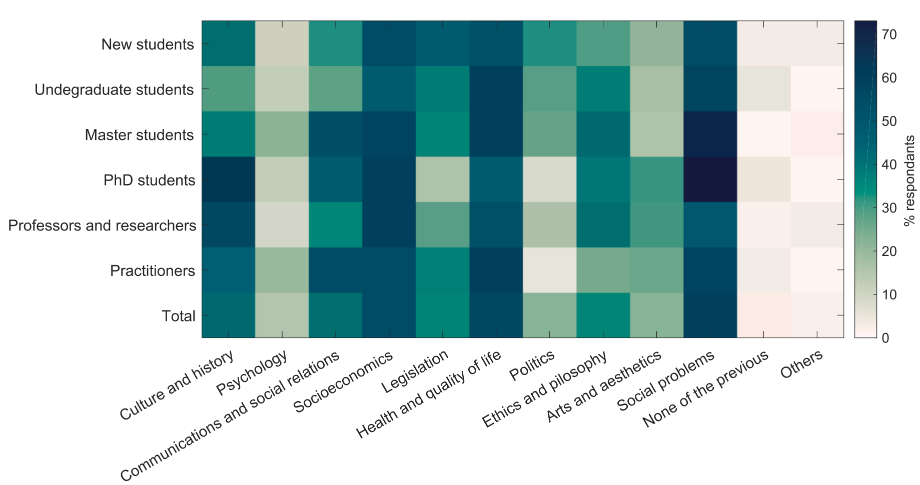

Fig. 4. Colourmap showing the answers to Q3 on the topics that should be included in the education of civil engineers.

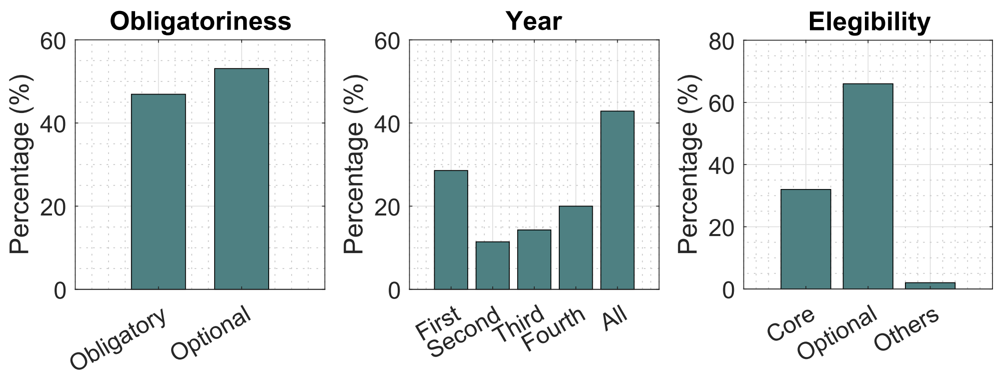

Fig. 5. Statistics concerning the indicators analysed in relation to obligatoriness, year and eligibility.

the results concerning three indicators: obligatoriness of the subject, the year in which the subject is taught, and its eligibility or not.

First, it can be seen that with regard to the year in which the subject is taught, there are two main trends. On the one hand, approximately 29% of programmes include SSH subjects in the first year, whereas more than 40% include them in the second year or later. The proportion of programmes in which these subjects are included solely in the second, third, or fourth year is relatively low. Secondly, as for the obligatoriness of SSH subjects, there is no substantial difference between programmes that make it compulsory to take SSH subjects and those that make it optional. Note that these results do not include programmes in which no SSH subject is available. Apart from discerning between whether the student needs to take the subject or not, it is also possible to compare whether this is a core or optional subject. In this case, more than 60% of the programmes allow students to choose what SSH subject to take, whereas around 35% offer it as a core subject that cannot be changed.

Fig. 6 shows the percentage of credits in the civil engineering undergraduate programmes from each university that correspond to SSH subjects. Fig. 6a shows the results obtained from all the universities analysed; Fig. 6b shows the proportion of credits corresponding to the cases in which they are obligatory, and Fig. 6c shows the results for those curricula that have SSH subjects specifically related to the field of civil engineering. In the three graphs, the red vertical line shows the mean percentage of credits corresponding to each case.

It can be observed that there is a decreasing trend in all the graphs. This means that there are fewer universities with a higher number of credits allocated to SSH. Regarding the obligatoriness of SSH subjects, a total of 35 programmes set them as obligatory, and they have an average of 7.4% of the credits in their programmes. Only 18 of the faculties considered in this study incorporate specific SSH subjects that relate to civil engineering, with these subjects accounting for 3% of total programme credits on average.

Finally, to analyse the possible relationships between the proportion of credits allocated to SSH and the ranking of the respective universities in the field of Civil Engineering, Fig. 7 shows data on the percentage of credits corresponding to SSH subjects together with the score for each university in the academic performance indicator. The green squared markers show programmes in which it is obligatory to take SSH subjects, whereas the red round markers correspond to programmes in which it is not compulsory to take them. Note, furthermore, that programmes not

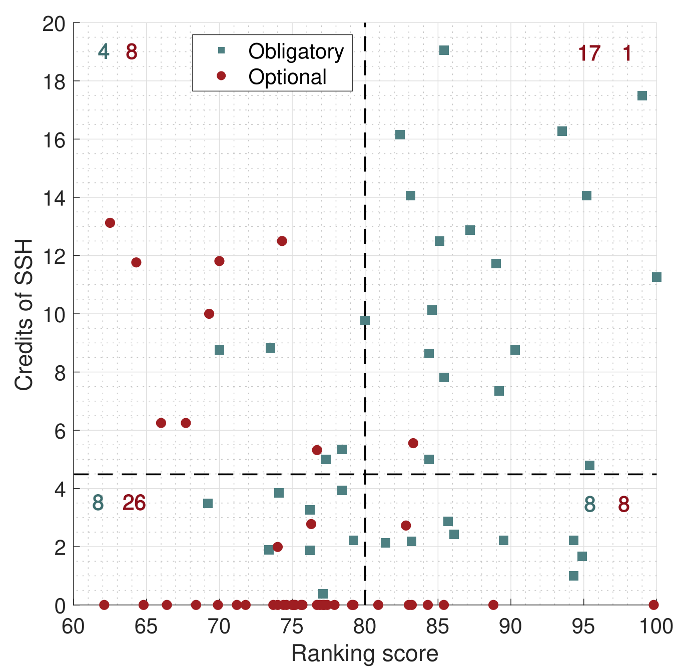

Fig. 7. Four quadrant chart of the credits allocated to courses with a primary focus on SSH of each programme, and respective academic ranking score.

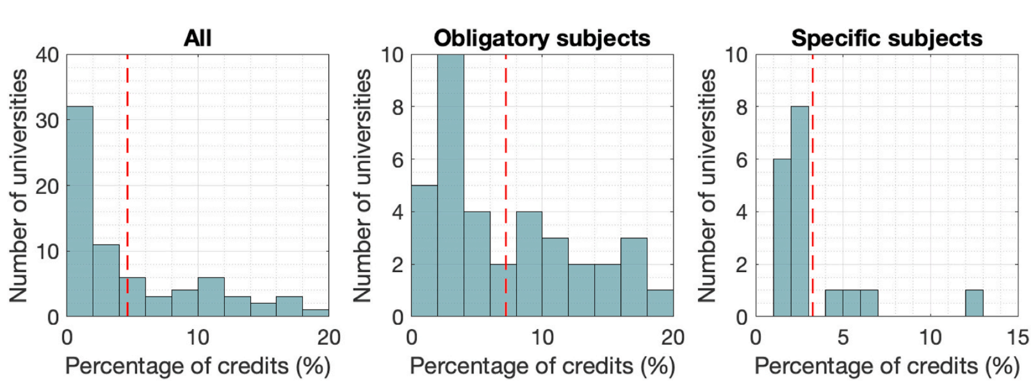

Fig. 6. Statistics of the indicators analysed in relation to the proportion of credits. The mean percentage of credits is shown by a red dotted line.

offering SSH subjects are also represented. They appear in the bottom line because the corresponding percentage of SSH credits is equal to zero. A dashed line has been plotted along the x and the y-axes to mark the mean of the corresponding variables represented on each axis. Besides, the number of markers of each colour located in each quadrant have been written in the corners of the chart.

The graph shows that in the top right quadrant there is a higher number of markers corresponding to university programmes that have obligatory SSH subjects in their syllabuses. On the contrary, in the bottom left quadrant, there is a more significant proportion of markers belonging to programmes without obligatory SSH in their curricula. The other two quadrants show similar proportions of the two typologies.

This shows that there is a high correlation between the ranking score in terms of academic indicators and the proportion of SSH credits that are included in the programmes. There are multiple, complex links between a programme's syllabus and its faculty ranking, because this affects both the inputs and outcomes directly and creates many positive and negative externalities. Fig. 7 provides evidence that the relationship exists between the two variables considered, and that an efficient allocation of SSH topics and subjects in programmes may be considered as a response to an effective improvement of academic outcomes.

Having said this, it is also necessary to examine the specific contents of the SSH credits analysed above. First, one relevant aspect to emphasise is that notably wide diversity exists regarding which SSH subfields are included in each programme. One element that adds to this variety is the fact that some universities offer a vast range of optional subjects, that are either provided by the engineering faculty or SSH faculties at the same university.

With regard to the subjects that have SSH as their primary focus, two main trends were observed in terms of how SSH were incorporated. On the one hand, among the degrees that offered SSH subjects, some had courses in the SSH area that were not specific to CE. Generally, these faculties offered the students the possibility of choosing one or more subjects from other faculties at the same university. It should be mentioned that the variety of possible choices for students is rather wide in this case.

On the other hand, the remaining universities analysed did offer SSH courses that were specific to CE. Two subjects that were relatively common in these cases were project management and economics for civil engineering. The other subjects that were found included the following areas: history of CE, health and safety, ethical and/or legal considerations in projects, culture, and humanitarian engineering.

In addition to the above, one common subject found in several universities was referred to as "Engineering in society". This subject belonged solely to the civil engineering degree in some cases, and in others, it was a general course to be taken by students from different engineering branches.

As for courses that did not have a primary SSH focus, there were two courses that proved to be relatively common for all faculties. On the one hand, courses connected to engineering sustainability were identified. These were courses that included conceptual aspects of sustainability in their syllabuses, as well as elements related to environmental impacts. Even though the social pillar of sustainability was not mentioned, it could be included in the course. On the other hand, there were courses that dealt with engineering design which were mainly based on students designing a project. In these cases, there was the possibility of incorporating a wide range of social issues, even though the project could also be purely focused on technical CE aspects.

Finally, some faculties offered either obligatory or optional courses, mainly focussed on transferable skills. Overall, the courses found in this area related to communication, both written and spoken.

4.3. Legal and institutional frameworks

Education accreditation profoundly influences the interdisciplinarity of CE programmes and, in particular, whether to include SSH content. The accreditation of an engineering programme makes it possible to evaluate and verify the quality of its services and operations through a quality assurance process. Accredited status is granted if the set standards are met. There are multiple accreditation criteria, not only related to an engineering education programme's social sensitivity. However, examining these criteria can give a better understanding of the overall relative importance that SSH are given in an engineering programme.

Consequently, the aspects within the multiple accreditation criteria that have been analysed are the specificity and depth of considering social aspects. As specified in section 2, a distinction is particularly made between the so-called more general transferable skills and technical skills related to specific areas of SSH. Accordingly, this examines the importance given to both types of skills as students' outcomes. As for the former, there is no agreed framework on what specific transferable skills are necessary for civil engineers. For instance, Suñé and Bonet (2014) consider five social competencies in engineering education: human interaction and versatility, facilitative leadership, teamwork, responsibility and active learning and initiative and innovation.

Before introducing the different accreditations in detail, it is important to emphasise that there are worldwide education agreements to recognise the equivalence of agreement signatories' accreditation systems. Two of the most widely known agreements in the field of engineering education that apply to civil engineering are the Washington Accord (established in 1989) and the Sydney Accord (established in 2001).

Regionally and internationally, two accrediting bodies stand out: ABET and the European Network for Engineering Accreditation (EUR-ACE). First of all, ABET accreditation identifies seven learning outcomes that students should attain during the programme: identification; formulation and solution of complex engineering problems; application of engineering design to produce solutions that meet various needs (safety, welfare, economic, environmental, social, etc.); effective communication; recognition of ethical and professional responsibilities in engineering situations and consideration of their impacts in different contexts; effective team-working; appropriate experimentation, analysis and interpretation of data; acquisition and application of new knowledge as needed.

Even though ABET criteria up to the year 2000 required inclusion of half a year of studies on humanities and social sciences in engineering studies, this was subsequently removed (Evans, 2007). Therefore, at present, even though transferable skills are considered in the accreditation criteria, technical knowledge on SSH is not. Among the students' outcomes, it is the second one that reflects a possible influence of SSH in curricula to a greater extent, which describes "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors."

The EUR-ACE framework provides standards and guidelines for engineering programmes and identifies eight learning areas: knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice, making judgements, communication and team-working, lifelong learning. On the one hand, technical knowledge on SSH is not systematically considered in the criteria for accreditation; it is only in the outcome "Making judgements" that social issues are considered, albeit superficially and lacks a specific definition of what this involves. On the other hand, transferable skills do appear as a requirement that students need to demonstrate by the end of the degree.

At local and national levels, other outstanding accrediting bodies include Engineers Australia, National Board of Accreditation of India, Japan Accreditation Board of Engineering Education, Institute of Engineers Singapore, Accreditation Board for Engineering Education of Korea, Engineering Accreditation Council of Malaysia, Institute of Engineering Education Taiwan.

While only a few of these accrediting bodies incorporate specific technical knowledge on SSH as required students' outcomes in the curricula of civil engineering programmes, most of them do include acquisition of certain transferable skills as a requirement.

For instance, in the Stage 1 competency standards for professional engineers for the Engineers Australia accreditation, what are referred to as human factors are included in two learning outcomes (learning outcome 1.5d, "Is aware of the founding principles of human factors relevant to the engineering discipline" and 2.3b, "Addresses broad contextual constraints such as social, cultural, environmental, commercial, legal, political and human factors, as well as health, safety and sustainability imperatives as an integral part of the design process"). The National Board of Accreditation of India incorporates the outcomes required by ABET, including the one emphasised beforehand, which is related to the consideration of social factors when designing engineering solutions.

However, in spite of the requirement for students to demonstrate knowledge and awareness in broad SSH areas, there is no guide on the right level and approach with regard to including SSH in engineering curricula.

As an exception, the Canadian Engineering Accreditation Board does have a requirement on the inclusion of SSH (Engineers Canada, 2019). It sets a minimum number of credits corresponding to "Complementary studies". Such studies may include "humanities, social sciences, arts, languages, management, engineering economics and communications."

Apart from accrediting bodies, there are numerous engineering education organisations and civil engineering professional institutions. They exist at different levels, ranging from local to international. Even though their relationship with university programmes is not as direct as that of accreditation bodies, they can play an essential role in the development and improvement of engineering education. They can also raise awareness on important issues for engineering education and the engineering profession, both among engineers and society. For instance, at regional levels, the European Society for Engineering Education (SEFI) and the American Society for Engineering Education (ASEE) are two of the best-known ones. Publications by both organisations showcase the need to incorporate a social dimension in engineering curricula (see, for instance, Titus et al., 2011; (van Hattum-Janssen et al., 2012; Adair and Jaeger, 2016; Nahas and Moubayed, 2015)).

It is also possible to find professional associations for specialised fields of engineering, such as ASCE and ICE. ASCE in particular has been boosting explicit inclusion of social factors in the education of engineers. They have developed a Body of Knowledge and advocated for considering the technical capacities of civil engineers as represented by four pillars: basic sciences, mathematics, humanities, and social sciences (Evans et al., 2007). Besides, "the vision for the civil engineer in 2025" (ASCE, 2007) stresses several aspects whose study is closely related to SSH. This document describes a roadmap for the civil engineering profession through five outcomes, which are respectively entitled "Master builders", "Stewards of the environment", "Innovators", "Managers of risk", and "Leaders of public policy".

In a similar vein, ICE has published a document defining its vision and strategy for the 2013–2025 period, under the title "Shaping the world" (ICE, 2013). This document still emphasises the role that civil engineering plays in achieving most sustainable development goals and in tackling some current global challenges which, the document states, are social, environmental and economic.

5. Discussion

5.1. Triangular analysis

Two main aspects need to be considered in the discussion of the above-presented results. These aspects derive from the triangular cross-examination of the analyses performed and are related to the current status of SSH in CE curricula and the barriers to effectively incorporating SSH in such curricula.

On the one hand, according to the answers provided by students, researchers, professors, and practitioners to the survey, SSH are perceived by most as an area where civil engineers should be knowledgeable at least up to a certain level. This is also supported by the targets set out by professional institutions of civil engineers, which emphasise the importance of social issues in professional practice.

Hence, even though there is a common conception, both in academia and practice, according to which the SSH area of knowledge should be introduced at HE levels, only a minority of civil engineering schools have included SSH in their curricula. Moreover, there is no common agreement among CE curricula regarding the characteristics that this kind of subjects should have in terms of the proportion of credits, obligatoriness, the academic year in which these subjects are taught, and eligibility of the subject.

Nevertheless, the results from this study reveal that there is indeed a relationship between the programme's ranking position in terms of academic indicators and whether or not they contain compulsory SSH contents. Higher positions in the ranking appear to belong to programmes in which there are more obligatory credits allocated to SSH, whereas lower positions in the ranking tend to belong to programmes in which there are few or no credits for obligatory SSH contents.

Regarding the specific content that is included, the range of SSH areas that are incorporated by different faculties is very wide. In extreme cases, students have the possibility of choosing any course from one or several SSH faculties within the same university. Such an approach has the advantage that students can choose according to their interests and can obtain in-depth knowledge of certain SSH subjects. Nonetheless, not contextualising the subject in the frame of CE can make it difficult for students to comprehend how such technical SSH knowledge can be applied in the context of CE.

This diversity in the methods in which SSH are introduced, and the contents that are included can be seen as the result of a lack of consensus among accrediting bodies, which have not yet introduced SSH subjects as a specific requirement in their criteria, as well as a lack of a specific SSH body of knowledge for civil engineers. The latter problem may be a consequence of the area of study still being in its infancy and of a dearth of discussions around this topic, both in academia and practice.

On the other hand, there are several barriers that hold back progress in this area. In particular, four main impediments have been detected. First, traditionally, civil engineering degrees have been seen as totally or almost totally technical. Changing this perception encounters what is referred to in the literature as resistance to change (Goldberg, 1996; Splitt, 2003; Besterfield-Sacre et al., 2014). In this context, this resistance may be linked to aspects such as the unwillingness of professors to modify subject programmes, the reluctance of departments to see their teaching subjects forced to include new subjects, or the difficulties that may be encountered in finding suitable professor profiles for such an approach. Apart from being a social issue, it involves bureaucracy as well, since different faculties have different degrees of autonomy when it comes to implementing changes in university programmes (Case et al., 2016).

Second, there is the influence that different stakeholders may exert on developing university curricula. Specifically, when these influences result in programmes designed according to the interests of a specific part of society rather than for students' professional development (for more information on this phenomenon, the reader is referred to Case et al. (2016) and Cas (2017).

Third, when attempting to restructure civil engineering programmes, there are no clear guidelines or study cases on the methodology and the contents that should be incorporated. As shown in the analysis of worldwide curricula, every programme has its singularities in relation to the characteristics of SSH subjects. In this regard, it is important to consider that the way in which social aspects are introduced will affect how these very same topics are perceived by students and professors. For instance, if they are made optional subjects, many stakeholders might be inclined to think that the subject is not particularly important. Also, the effect that an SSH subject has on the students' development may differ depending on whether the subject comes in the first or the last years of the degree.

Besides, before implementing this type of subjects, it is also fundamental to consider whether SSH contents should be included as specific subjects or as a transversal topic throughout all years of study.

Finally, there appears to be a misconception on the social side of civil engineering. In particular, some students consider that factors such as "climate change" and "CO_2 emissions" fall within the area considered as SSH in civil engineering. Consequently, a false truth may be obtained when analysing, through surveys, the extent to which students and researchers are knowledgeable in these fields. This actually represents a limitation to the survey that was carried out as part of this research.

5.2. Introduction of SSH in CE education: proposal

A fundamental factor to consider in terms of introducing SSH in the education of civil engineers is whether such contents should be introduced in the curricula as transversal areas of expertise or as specific subjects in the syllabus. In the latter case, the question also arises of whether these topics should be general SSH subjects, such as psychology or sociology, or should concern topics that are more specific to CE, such as inequalities in transport or environmental justice.

In light of the above, three basic methods of introducing SSH issues can be identified: transversal, introducing general SSH subjects, or introducing specific SSH subjects. These are methods that are complementary rather than supplementary. Ideally, SSH contents should be introduced transversally in relevant major parts of the subjects. Unfortunately, the current lack of SSH knowledge among students may force the introduction of teaching modules solely focused on SSH topics. In this case, it may be adequate to introduce such subjects with contents that are specifically oriented towards civil engineering, because in this way, students will encounter fewer difficulties in understanding how such contents can be applied in practice, which could, in turn, make the courses more appealing for them.

Leaving aside the discussion with respect to the specific and most adequate method or combination of methods, as a first tangible step to the introduction of SSH in civil engineering programmes, we propose fundamental social contents that may be incorporated in CE education. To this aim, we draw on the results presented in Section 3 and on two main publications. First, Stroeken and de Vries (1995) propose a checklist of aspects that could be of importance in engineering studies. Their work does not focus on a single engineering field, and therefore, we complement it with the work by Josa and Aguado (2019). In their publication, they propose a framework that describes the relationship between SSH and CE, and that can either be used in professional or academic environments.

Josa and Aguado (2019) consider three topics to be transversal to the intersection between SSH and CE: stakeholders, time, and others (see Table 3). These can either be introduced as whole subjects or, preferably, as topics within civil engineering subjects.

The same authors (Josa and Aguado, 2019) also determine topics that can be incorporated specifically for each field within civil engineering (transport, water technology, energy technology, environment technology, urban planning and buildings). Table 4 shows topics that can be introduced in each of these specific sub-fields (as identified by Josa and Aguado, 2019). Because of the breadth of the field, the list is not exhaustive, but it does aim to cover most of the essential existing contents. Note that some of them may be repeated in different areas and that some of them may be adapted to be treated in areas other than specified.

Table 3
Transversal topics.

Areas	Topics (transversal)
Stakeholders	Stakeholder mapping and characterisation, different levels of stakeholder participation, conflict management, information communication.
Time	Impacts and project considerations related to the different stages of the lifecycle of public works, namely: design and planning, construction, operation and maintenance, and decommissioning.
Others	Current global issues, ethics, social responsibility, poverty, distributive justice and spatial inequalities, health, safety and security, politics, governance, cultural heritage, history and development of the profession of civil engineering, social impact assessment methods.

6. Conclusions

In the last decade, the potential contribution that SSH can make to STEM fields has been increasingly acknowledged. STEM and SSH coexist and interact in several different ways that can enrich both academic research and professional practice. Even though some STEM fields have already made significant progress towards integrating different domains within SSH, other fields are still in their infancy in terms of such consolidation.

In particular, the field of CE still needs to advance towards such an interdisciplinary approach. This need arises from the fact that current societal challenges related to the field of civil engineering lie less in the development and application of sophisticated technologies, and more in their adequacy in terms of economic, environmental and social sustainability. Hence, it is essential to incorporate SSH as a pillar in the education of civil engineers.

This paper has analysed how SSH are currently perceived and implemented in civil engineering HE programmes. For the analysis, a triangular approach has been taken where information from field surveys and bibliographic research has been combined to better understand the current role of SSH in universities and to propose methodologies through which social topics can be introduced in formal HE programmes. Such analyses also helped reinforce the need to consolidate a CE body of knowledge that is comprised both of technological and SSH technical knowledge.

There are two main directions that HE institutions, and in particular, CE faculties, should work towards to develop adequate programmes to train future professionals with the knowledge and skills to tackle some of the world's most overarching current problems. On the one hand, it is necessary to implement relevant aspects from the SSH transversally in civil engineering programmes. Nevertheless, it is true that such transversal implementation could be challenging due to the current general

Table 4
Specific topics.

Fields	Specific topics
Transport	Use patterns, cultural and sociological factors affecting demand and consumption, local/regional social interactions and communications, accessibility and affordability, health and security, political interests, transport governance, right to mobility, transport justice.
Water technology	Consumption patterns, water governance, water resources management, stakeholder participation, water poverty, water justice, water distribution and spatial inequalities.
Energy technology	Cultural factors affecting demand and consumption, attitudes and behaviours towards technologies, energy poverty and vulnerability, energy governance, energy justice.
Environment technology	Influence of cultural factors in the adoption of technologies, attitudes and behaviours, informal sector, effect on health and quality of life, health vulnerability, environmental justice.
Urban planning	Tangible manifestations of human culture, relation between urban change and culture, behaviour patterns, symbolic values of urban areas, social participation, urban laws and regulations, physical and mental health, urban governance, urban justice, urban barriers, exclusion.
Buildings	History and development, symbolic values, accessibility, affordability, construction laws and regulations.

lack of foundational knowledge in relevant fields of SSH among civil engineering students. One possible alternative could be to introduce specific subjects on the main social topics concerning civil engineering. Apart from specific technical skills, development of certain transferable skills should also be encouraged to train future professionals with the knowledge and skills to tackle some of the most overarching current problems.

Finally, four main barriers have been identified in the achievement of the above-mentioned objectives. These are: (1) resistance to change, (2) external influences on the curricula, (3) lack of guidelines, and (4) misconceptions on what is meant by incorporating SSH in civil engineering education.

Future studies should focus on examining how SSH have been incorporated into other STEM fields, such as in energy or climate change research, as well as identifying which areas within the SSH should be prioritised in CE programmes.

CRediT authorship contribution statement

I. Josa: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **A. Aguado:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Irene Josa was supported by the Catalan Government through the grant of Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR), with reference number 2018 FI_B 00655.

The authors would also like to thank professors Napoleón Anento, Irene Arias, Miquel Estrada, Nieves Lantada, Eva Oller, Mariàngels Puigví and Francesc Robusté for the support given during the distribution of the surveys, and to Nirvan Makoond for proofreading.

Appendix

Table 5 shows the list of all the universities that have been analysed for the comparison of civil engineering syllabuses. The table shows the country in which they are located and their position according to the QS ranking.

Table 5
Universities analysed, together with their country and position in the QS ranking

Position	University	Country
1	MIT	USA
2	National University of Singapore	Singapore
3	University of California, Berkeley	USA
4	Delft University of Technology	Netherlands
5	University of Cambridge	UK
6	Imperial College of London	UK
7	Politecnico di Milano	Italy
8	ETH Zurich	Switzerland
9	Tsinghua University	China
10	Nanyang Technological University (Singapore)	Singapore
11	Ecole Polytechnique Federale de Lausanne	Switzerland
12	UNSW Sydney	Australia
13	Stanford University	USA
14	Georgia Institute of Technology	USA
15	Hong Kong Polytechnic University	Hong Kong
16	University of Oxford	UK
17	Hong Kong University of Science and Technology	Hong Kong
18	University of Hong Kong	Hong Kong
19	University of Tokyo	Japan
20	University of Sydney	Australia
21	University of Illinois at Urban-Champaign	USA
22	University of Melbourne	Australia
23	Universitat Politècnica de Catalunya	Spain
24	Kyoto University	Japan
25	Politecnico di Torino	Italy
26	University of Texas Austin	USA
27	Shanghai Jiao Tong University	China
28	KAIST	South Korea
29	Purdue University	USA
30	Monash University	Australia
31	Seoul National University	South Korea
32	University of British Columbia	Canada
33	University of Western Australia	Australia
34	University of Michigan	USA
35	University of Toronto	Canada
36	University of Queensland	Australia
37	National Taiwan University	Taiwan
38	Pontificia Universidad Católica de Chile	Chile
39	University of Auckland	New Zealand
40	Tongji University	China
41	University of Manchester	UK

(*continued on next page*)

Table 5 (*continued*)

Position	University	Country
42	Tokyo Institute of Technology	Japan
43	KTH Royal Institute of Technology	Sweden
44	University of Sheffield	UK
45	Universidad Politécnica de Madrid	Spain
46	Universidade de Sao Paulo	Brazil
47	Texas A&M University	USA
48	Hanyang University	South Korea
49	National Technical University of Athens	Greece
50	Technical University of Denmark	Denmark
51	Universidad Nacional Autónoma de México (UNAM)	Mexico
52	California Institute of Technology (Caltech)	USA
53	Carnegie Mellon University	USA
54	Chalmers University of Technology	Sweden
55	City University of Hong Kong	Hong Kong
56	Columbia University	USA
57	Cornell University	USA
58	Curtin University	Australia
59	Ecole des Ponts ParisTech	France
60	Indian Institute of Technology Bombay (IITB)	India
61	Indian Institute of Technology Delhi (IITD)	India
62	KU Leuven	Belgium
63	KIT, Karlsruhe Institute of Technology	Germany
64	Korea University	South Korea
65	McGill University	Canada
66	Northwestern University	USA
67	Norwegian University of Science And Technology	Norway
68	Université PSL	France
69	Peking University	China
70	Pennsylvania State University	USA
71	Princeton University	USA
72	Queensland University of Technology (QUT)	Australia
73	RWTH Aachen University	Germany
74	RMIT University	Australia
75	Sapienza University of Rome	Italy
76	Technical University of Munich	Germany
77	The University of Adelaide	Australia
78	University of Nottingham	UK
79	UCL	UK
80	Universitat Politècnica de València	Spain
81	University of Naples - Federico II	Italy
82	Universiti Malaya (UM)	Malaysia
83	Universiti Teknologi Malaysia	Malaysia
84	University of Birmingham	UK
85	University of Bristol	UK
86	University of California, Davis	USA
87	University of California, Los Angeles (UCLA)	USA
88	University of Canterbury	New Zealand
89	The University of Edinburgh	UK
90	University of Leeds	UK
91	University of Lisbon	Portugal
92	University of Porto	Portugal
93	University of Southampton	UK
94	University of Technology Sydney	Australia
95	University of Waterloo	Canada
96	University of Wollongong	Australia
97	Vilnius Gediminas Technical University	Lithuania
98	Virginia Polytechnic Institute and State University	USA
99	Yonsei University	South Korea
100	Zhejiang University	China

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