EPS@ISEP: Mapping Sustainability

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Abstract

The European Project Semester (EPS) is a project-based learning framework designed to prepare engineering undergraduates for future professional challenges. During one semester, multicultural multidisciplinary teams design, develop and test solutions to real problems affecting the planet, society or individuals, considering technical, sustainability, ethical, and market requirements. The implemented learning process gives teams the autonomy to make design decisions, as long as they are based on clear sustainability and ethical criteria. The aim is for students to develop skills not only in critical thinking, problem-solving, creativity, innovation, effective communication, collaboration, and teamwork, but above all, the ability to make decisions based on ethical and sustainability principles. This study aims to demonstrate that EPS@ISEP effectively contributes to the development of sustainability-oriented engineers. To this end, it compiles evidence found at the institutional level, represented by programme documentation, and the student level, represented by team deliverables. The method involves semi-automatic mapping of sustainability keywords compiled from the documents, as well as by other researchers. The results show that both the institution and the participants are aligned and committed to the design of sustainability-driven solutions.

Keywords: Engineering Education for Sustainable Development, European Project Semester, Project-Based Learning, SDG mapping

Introduction

Engineering education for sustainable development (EESD) focuses on integrating sustainability principles into engineering curricula to prepare future engineers to address global challenges. It emphasises the development of skills and knowledge that enable engineers to contribute to the United Nations' (UN) Sustainable Development Goals (SDGs), such as environmental protection, social equity, and economic viability. The European Project Semester (EPS) is a semester-long student-centred programme created by Arvid Anderson in 1995 [1]. Currently, it is offered to advanced undergraduates enrolled in engineering and related studies by a group of 20 universities[1] – the EPS providers – located in 13 European countries.

EPS binds providers to following the 10 Golden Rules of EPS[2], while, at the same time, providing freedom in how the programme is implemented locally. In this way, providers can capitalise on their know-how, creating unique EPS implementation profiles. In particular, EPS at the Instituto Superior de Engenharia do Porto (EPS@ISEP) combines project- and challenge-based learning with international multidisciplinary teamwork and problem solving guided by ethical and sustainability concerns to prepare future engineers [2]. The aim is to encourage participants to become lifelong learners and agents of sustainable development. This is achieved by proposing open-ended real-world challenges, coaching rather than supervising, and fostering autonomous teamwork and sustainability-driven decision making.

This work revisits and integrates the results of previous sustainability mapping applied to programme documentation and team deliverables to determine whether EPS@ISEP implements EESD and whether participants acquire the desired competencies [2–5]. The following sections review sustainability mapping, detail the method used, summarise the results and findings, and present the conclusions of this research.

Sustainability Mapping

The incorporation of sustainability and Sustainable Development Goals (SDGs) [6] into engineering education is crucial to prepare future engineers to face global challenges. This involves embedding sustainability principles and SDGs into the curriculum and learning process, ensuring that graduates are equipped with the knowledge and skills to contribute to sustainable development. One way to determine whether a study programme equips students with such competencies is sustainability mapping.

Sustainability mapping has been applied to identify research contributions that align with the UN's SDGs. In 2023, Wang et al. [7] introduced a new method based on Elsevier's previous SDG mapping efforts. This method uses text-mining and n-gram analysis to extract global and local SDG-related keywords from publication metadata, such as titles, keywords, and abstracts. The keywords are then sorted by frequency and relevance, followed by a manual review to ensure they are meaningful. The final list of SDG keywords is called the Auckland list. More recently, Kashnitsky et al. [8] outline another methodology to map research to the UN's SDGs, adopted by Times Higher Education for its Social Impact rankings, and benchmark existing approaches using existing SDG validation datasets.

[1] https://europeanprojectsemester.eu/providers
[2] https://europeanprojectsemester.eu/concept

In this work, keyword and query-based mapping techniques are used to assess the alignment of the learning process with sustainability principles and the SDGs. These methodologies often involve text mining and natural language processing to analyse documents, as proposed by [9–11]. Specifically, Thomas et al. [9] define a methodology to quantify the coverage of SDGs within university course curricula. The study employs a keyword scanning tool to analyse course learning outcomes, identifying the presence of SDG-related terms. The researchers used ChatGPT to enrich the keyword list, generating contextually relevant synonyms. A survey was also conducted among faculty members to gather their perceptions of SDG coverage in their modules. The integration of ChatGPT-derived synonyms improved the accuracy of the keyword scanning tool. A comparison between methodology outcomes and faculty survey responses revealed a more comprehensive identification of SDG-related content, highlighting areas for potential curriculum enhancement. Li et al. [10] share an open-source tool to assess the alignment of textual data with the SDGs, namely academic publications, course descriptions, and policy documents. The tool uses a predefined set of keywords and phrases associated with each goal and performs a frequency analysis to gauge SDG alignment. Lemarchand et al. [11] introduce a technique to measure the alignment between university curricula and the SDGs. It builds a sustainability lexicon of root keywords based on a corpus of sustainability documents by adapting the Term Frequency–Inverse Document Frequency (TF-IDF) method. This approach captures the relative importance of terms associated with each SDG.

In line with the above research, the sustainability mapping methods applied to the EPS@ISEP documents implement text mining, along with lists of keywords related to sustainability and the SDGs. This allows the identification and quantification, mainly through TF, of sustainability evidence in EPS@ISEP documents, such as the presence of keywords associated with SDGs and other significant relationships.

Mapping

The search for evidence of EESD and, consequently, alignment with the UN's SDGs was applied to the programme materials (syllabus, project briefs, and document templates provided to the teams) and the team deliverables (reports and technical and scientific papers). Programme materials reflect the institution's views on sustainability, while team deliverables reflect those of the students. The proposed method, summarised in Figure 1, applies text mining techniques to both collections to perform semi-automated keyword (term) mapping.

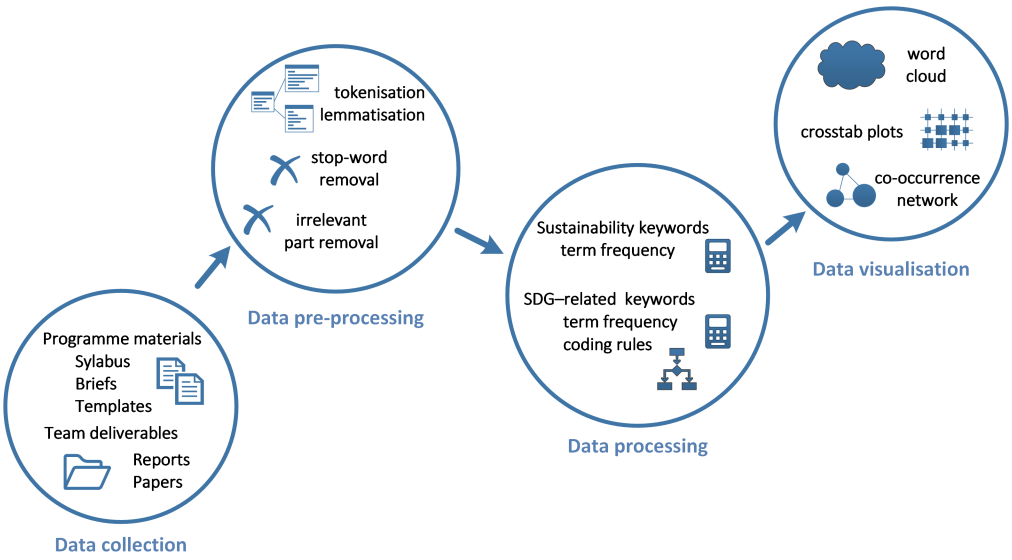


Fig. 1 Sustainability mapping pipeline.

Programme Materials

The analysed materials comprise the EPS@ISEP syllabus, project proposals (here called briefs due to their short and open-ended nature), the brief template, and the report template.

Team Deliverables

Text mining was applied to student reports and papers using KH Coder, a computer software package designed for quantitative content analysis and text mining. It is a versatile tool that allows researchers to explore and extract meaningful insights from textual data, namely word clusters, descriptive statistics like term frequency, term frequency distribution (TF), document frequency distribution (DF), TF-DF plots, word association, and co-occurrence networks of words [12].

This semi-automated analysis maps the contents of documents against a given list of terms. The list of sustainability-related keywords used with the reports was compiled directly from the reports by the authors, while the list applied to the papers was compiled by the University of Auckland [13] to identify research contributions that align with the UN's SDGs. The list made by the authors covers the use of resources, quality of life, environmentally friendly technology, and social and environmental responsibility. The list compiled by Auckland identifies a collection of terms related to sustainability and associates them with the 16 SDGs, so it is a list of SDG-related keywords. In this way, it allows both the detection of keywords related to sustainability and the identification of the associated SDG.

(i) Reports

The analysis examines both the full text and individual chapters or sections. The method involves five steps: (i) pre-processing to remove irrelevant parts (student names, numbers, captions, template headings, acknowledgments, references) and stop words, text tokenisation, and

word lemmatisation; (ii) automatic generation of the term-frequency (TF) list; (iii) manual identification of the sustainability-related term-frequency (SRTF) list; (iv) creation of the global word cloud of the SRTF found using WordClouds.com[3]; and (v) generation of the co-occurrence network between the TF list of the chapter parts and the SRTF list [2].

(ii) Papers

This analysis considers three datasets, containing all keywords by field and individual paper, and reuses the SDG-keyword list from the University of Auckland [5]. Team papers typically identify the main SDGs they contribute to.

The method creates sixteen SDG queries (KH Coder coding rules) followed by contingency and co-occurrence analyses to identify the links between SDG categories and paper contents. First, pre-processing removes irrelevant parts (author information, affiliation, figures, tables, acknowledgements, references) and stop words, tokenises the text and lemmatises the words. During processing, it calculates the frequency of occurrence of the SDG keywords globally, per field and by paper, considering the fact that most keywords are compound rather than single words. Next, it applies the sixteen KH Coder coding rules to the different datasets to generate the global word cloud, by field and by paper results. These rules implement the SDG queries, connecting the SDG keywords of each SDG category with the appropriate Boolean operators. The coding rules map the document contents to each SDG, providing the input to create: (i) the contingency table known as frequency-based cross-tabulation matrix, containing the observed counts of SDG categories within the papers; and (ii) the semantic network referred to as co-occurrence network, displaying the coincidence of SDG categories in individual papers or by field.

The results have been visualised as a word cloud of the SDG-related keywords found globally using WordClouds.com, cross-tabulation plots showing the relative frequency of SDG categories in individual papers as well as by project field, and the co-occurrence network graph displaying the coincidence of SDG categories in individual papers.

Results

The experimental data were retrieved from institutional repositories (syllabus[4], project briefs[5], brief and report templates[6], and project reports[7]) and scientific repositories (project papers[8]).

Programme Materials

The EPS@ISEP syllabus includes two project support modules related to sustainability: “Ethics & Deontology” and “Energy & Sustainable Development”. The project brief template has two main fields: the goal and the default requirements. The goal, which describes the problem in broad terms, also states that the “purpose, target user segment and the full set of solution requirements are to be defined by the team based on the state of the art, marketing, sustainability

[3] https://www.wordclouds.com/
[4] https://www.isep.ipp.pt/Course/Course/44#plan
[5] https://www.ave.dee.isep.ipp.pt/~mbm/PROJE-EPS/2324/Proposals/EPS_PROJECT_2024_T4.pdf
[6] https://www.eps.dee.isep.ipp.pt/doku.php?id=report
[7] Start at https://www.ave.dee.isep.ipp.pt/~mbm/EPSatISEP/, scroll through the years, and select the wiki of each team to access the respective project report.
[8] Search for ‘EPS@ISEP’ in the Polytechnic of Porto repository (https://recipp.ipp.pt/).

and ethical analyses". The requirements specify a maximum budget, the fulfilment of the applicable European directives, and the mandatory adoption of the International System of Units, open-source software, and low-cost hardware. Regardless of whether projects directly address sustainability issues, they consistently focus on designing innovative sustainable solutions [2]. Finally, the report template comprises eight mandatory chapters: "Introduction", "State of the Art", "Project Management", "Marketing Plan", "Eco-efficiency Measures for Sustainability", "Ethical and Deontological Concerns", "Project Development" and "Conclusions". The chapters "Eco-efficiency Measures for Sustainability" and "Ethical and Deontological Concerns" are intended for teams to derive requirements that mitigate the ethical and environmental impact of their design. These results show that the programme has a strong focus on ethics and sustainability.

Team Deliverables

The analysis of the reports and papers was performed with different keyword lists.

(i) Reports

The method was successfully applied first to a dataset of 19 project reports produced from 2011 to 2015 [2] and later to a set of three project reports related to smart cities [4]. The list of sustainability keywords used was compiled directly from the reports. In the first case, the analysis of sustainability-related terms co-occurrence in the chapters provided an important insight: sustainability is a pervasive concern within the reports since it is not confined to dedicated chapters, sections, or appendices. This finding indicates students were able to incorporate sustainability into their practice (project design and development). In the second case, the analysis focused on the centrality, frequency, and relations between the sustainability-related terms found in the three projects related to smart cities. The most central terms were team, *member, problem, improve, pollution, reduce, environmental, sustainable, energy and solar*, indicating that concerns about sustainability are very present.

(ii) Papers

The method was applied to a set of fifteen project articles, written from 2012 to 2023, which address problems in the fields of education, environment, food production, and smart cities [5]. The list of SDG keywords employed was compiled by the University of Auckland.

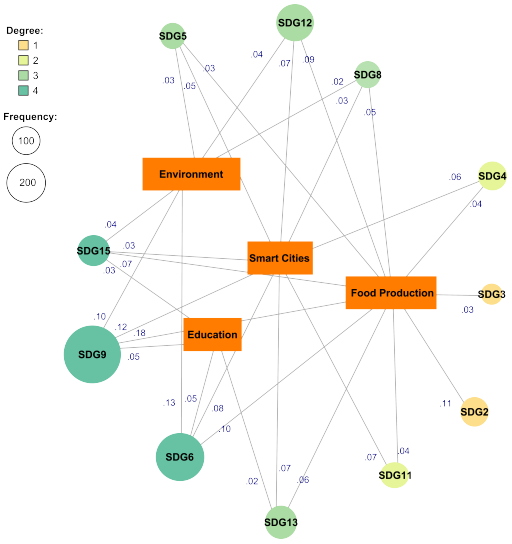
Figure 2 presents the global results from papers and by project field: Figure 2a displays the cloud of sustainability keywords; Figure 2b is the cloud of SDGs found in the paper dataset; Figure 2c shows the SDG co-occurrence network; and Figure 2d is the SDG heat map based on project field. The first pair of figures displays the keywords found and associated SDGs, representing their relative frequency of occurrence through font size. The top-six keywords in Figure 2a are *waste, air quality, recycling, food waste, water quality and pollution*. As displayed in Figure 2b, the most frequent SDGs are SDG 9 (Industry, Innovation and Infrastructure), SDG 6 (Clean water and sanitation), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

The second set of figures quantifies the relationship between the identified SDGs and the education, environment, food production, and smart cities project fields. In Figure 2c, the SDGs found are represented as circles with an area corresponding to their relative frequency, with fields as rectangles, and the relationship between fields and SDGs represented as lines with weights. It becomes clear that SDG 9, SDG 6, and SDG 15 (Life on Land) are transversal to all four project

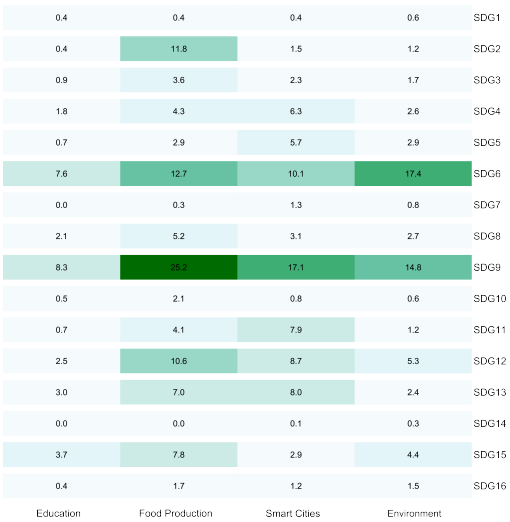
fields, whereas SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action) are present in at most three of the four project fields. The remaining SDGs found co-occur in two or in just one of the four fields. The contingency analysis, represented as a heat map in Figure 2d, quantifies the frequency distribution of SDGs by project field. The top three SDGs found across all fields are, as expected, SDG 9, followed by SDG 6 and, finally, SDG 12. Projects on food production and smart cities typically include more SDGs than those on the environment and education. The results show evidence of the processed papers being related to the SDGs and therefore support the development of sustainability competencies.

(a) Global keyword cloud.

(b) Global SDG cloud



(c) SDG co-occurence by project field.



(d) SDG heatmap by project field.

Fig. 2 SDG-related keywords in the paper dataset (globally and by project field).

Conclusion

The findings of this study demonstrate that EPS@ISEP effectively embeds sustainability into engineering education at both the institutional and student levels. The analysis of programme materials – syllabus, project briefs, and brief templates and reports – confirms that sustainability and ethics are central components of the curriculum. The inclusion of project support modules, such as "Ethics & Deontology" and "Energy & Sustainable Development", alongside sustainability-focused project requirements, indicates a strong institutional commitment to EESD.

At the student level, the text-mining analysis of team deliverables – reports and papers – further supports the conclusion that participants actively engage with sustainability concerns. The presence of sustainability-related keywords across multiple sections of project reports suggests that students do not merely address sustainability in dedicated chapters, but integrate these considerations throughout the project development process. Furthermore, the SDG mapping of team papers indicates that EPS@ISEP projects contribute to the practical application of SDGs, particularly SDG 9 (Industry, Innovation and Infrastructure), SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). Projects in food production and smart cities are the top contributors to the SDGs.

These results provide evidence that EPS@ISEP implements EESD, promoting awareness and concern for sustainability among participants. By integrating interdisciplinary teamwork, ethical reflection, and sustainability-driven problem-solving, the programme equips future engineers with the necessary skills to address complex global challenges. Future research could explore additional methodologies, such as AI-enhanced text analysis, to refine and further validate sustainability mapping approaches in engineering education.

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