EMBEDDING CLIMATE CHANGE GOALS IN ENGINEERING CURRICULA

Vladimir Stankovic* and Lina Stankovic*

Dept. of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, UK

Abstract: The paper describes the design and evaluation of group project-based approaches for embedding climate change and sustainability in final year undergraduate and postgraduate engineering taught classes at the University of Strathclyde, enrolling students with diverse backgrounds. The methodology will be illustrated via two case studies: a two-semester long image and video processing group project exploring algorithms that mitigate the effects of climate change, and a half semester long cooperative learning-based project where students reflect on how digital communications standards enable engineering solutions to tackle the United Nations sustainable development goals. Besides developing a deep appreciation of how theory links to practice in the fundamental building blocks of engineering design and implementation, the group projects develop collaborative working, creative thinking, cooperative learning, good engineering practice through reproducibility of approaches and how they can contribute to the sustainability agenda. Qualitative and quantitative feedback was collected from the students and analysed, indicating a predominantly positive learning experience.

Keywords: engineering education, sustainable development, climate change, project work, cooperative learning, sustainability development goals

**Correspondence to: Vladimir Stankovic and Lina Stankovic. E-mail: {vladimir, lina}.stankovic@strath.ac.uk*

1. INTRODUCTION

The need to embed the United Nations (UN) Sustainability Development Goals (SDG) (UN, 2015) into higher education curricula is widely established, together with the critical role universities need to play in addressing sustainability through education (Yáñez, et al. 2019). In this direction, in 2017, The University and College sector's collective response to the global goals was drafted, SDG Accord (SDG), whose goal is to identify the central role the education sector plays and should play in delivering on SDGs. To motivate the sector to work towards addressing SDGs, many higher education assessment and ranking methods, including The Times Higher Education University Impact Ranking, now include assessments on how far universities go to meet SDGs (THE, 2020). Driven by these motivators, besides embedding sustainability in estates, universities worldwide have tasked academic staff in investigating approaches to map SDGs into their curricula. While the general role of education in climate change and SDGs can be explored in earlier years or less specialist subject modules, the exact role a particular specialist engineering module can play in addressing SDGs remains a challenge since SDGs tend to require collaborative efforts bridging multiple disciplines (Willott, 2008). So far, at university level, climate change and SDGs have mostly been explored broadly in politics, social sciences, ethics, tourism, education, and business (Gil-Doménech, 2021), and to a lesser extent in engineering subjects. However, engineering, science and technology play a key role in achieving SDGs (UN, 2015), thus it is essential for *engineering students,* at all level*s,* to develop an appreciation of climate change challenges and SDGs as well as develop the relevant competences to tackle climate change and SDGs in their future professional careers.

A lot of research effort has been put in identifying competencies that need to be developed to meeting SDGs (UNESCO, 2017), including critical thinking, integrated problem solving, collaboration, system thinking, etc. There has also been extensive study on which SDGs learning objectives should be included in all or some engineering curricula (see, e.g., Sanchez-Carracedo, 2017). Sanchez-Carracedo et al. 2017 propose an Engineering Sustainability Map that contains learning outcomes that any engineering student should acquire. Chang and Lien (2020) discuss the inclusion of SDGs across different colleges of National University of Kaohsiung, concluding the importance of transdisciplinary developments. Furthermore, Annan-Dian and Molinari (2017) demonstrate the importance of interdisciplinary education for sustainable development.

This paper is a practice paper that presents an attempt to embed SDGs and climate change themes into university engineering teaching curricula, by setting two learning objectives: (1) the students should develop practical engineering skills needed to address SDGs and climate change challenges, (2) the students should develop an appreciation of the wider role of their specialist subject topic in tackling SDGs. With these two learning objectives in mind, this paper will present two case studies of how SDGs can be embedded into taught classes based on student-led open-ended project activities. In essence, our aim is to develop a creative learning environment where, through problem-solving activities, students are challenged to think how the knowledge gained in engineering taught modules can contribute to sustainability, by contextualising SGDs in practical scenarios. By working together to design engineering solutions that can support the sustainability agenda, the student will develop subject-specific competences that reinstate the material covered in the class, as well as transferable skills related to creative thinking, problem solving, and collaboration (UNESCO, 2017) towards sustainable behaviour starting from individual contribution and scaling up towards collective attitudes. The former is achieved by relating competences gained through material covered in the class, whilst the latter by moving away from generic concepts and goals stated in 17 UN SDGs, to daily-life issues, such as waste recycling. The collective work (i.e., within a group) enables fusing different ideas, individual views and SDGs contextualisation, and serves as an additional motivating factor that supports learning.

At the same time, recognising importance of inter-disciplinary work in developing SDGs related competences (Annan-Dian and Molinari (2017); Chang and Lien (2020); Ely et al. (2020)), the first example that will be described, builds a stimulating learning environment in a heterogenous class that comprised engineering and science student cohorts with different learning backgrounds. This paper will first describe, in Section II, the background of the two case studies, including the class structure and the subject covered. In Section III, the project design methodology is presented. In Section IV, qualitative and quantitative feedback from students involved is analysed.

2. STUDY BACKGROUND

In this section, the two classes at the University of Strathclyde (UoS) are described. Project learning objectives and outcomes were managed via UoS Virtual Learning Environment, MyPlace.

2.1 Case Study One: Image and Video Processing Class

The first studied case is a class that brings together 5-th year Electronic and Electrical Engineering (EEE) MEng and EEE Masters students, as well as two cohorts of doctoral students recruited as part of two centers for doctoral training that mainly recruit students with science backgrounds (e.g., biology, physics) and without engineering/ICT experience. The first group of students (EEE MEng + MSc) will be referred to as engineering students, while the second will be referred to as science students. The first group of students follows the class over two semesters with three and two contact hours per week in Semester 1 and Semester 2, respectively. The second group of students is enrolled during Semester 1 only and are assessed at the end of Semester 1.

2.2 Case Study Two: Information Transmission and Security Class

The educational aim of this elective module for 4th year Computer and Electronic Systems and EEE students is to solve unseen complex problems for physically transmitting information with varying levels of security and implement the techniques by which digital communication systems can be analysed and designed. In particular, the learning outcome being assessed by the group project was hypothesizing on the function of the building blocks of a digital communications system, establishing the performance of selected blocks analytically and selecting appropriate operational parameters to realise a required performance for a particular communications standard. The outcome of this summative four-student group project was a short 5-min video lesson, which would reflect about 20 hours of effort by each student. As part of their discussions, each group was asked to reflect how their digital communications standard could help tackle UN SDGs. The class was given 5 weeks to research their standard and link to the theory being taught in class. Students were grouped following the selection of standards they would prefer to explore in depth.

3. METHODOLOGY

3.1 Case Study One: Image and Video Processing Class

Working towards educational aim to provide hands-on experience in processing and analying visual signals, the students were organised into groups, to work on a joint open-ended project, defined as a piece of work that requires design of an image processing method, implementation of the design, validation and testing, and critical analysis of the obtained results. After the completion of the project, the students should gain subject-specific competences including abilities to comprehensively critically analyse literature and engineering systems, and a range of transferable skills, such as abilities to search and gather information from various sources, work collaboratively, document and report the work, and argumentatively discuss the approaches taken. Though a list of suggestions were given to the students, the students were encouraged to work as a group and creatively find problems where image processing could help towards sustainability. Each group comprised 2 or 3 science and 5 engineering students. Science students were tasked to framed the problem tackled, identify a range of technologies that can be used, and perform a critical literature analysis and put the work in the sustainability context. Furthermore, working with the engineering students, they set clear and measurable objectives and provide recommendations for the methodological steps. During this exercise, engineering students act as ‘clients’ who come with their requirements in terms of implementation limitations, time constraints, availability of data and skills in the group. While providing input to formulating project objectives and methodology, engineering students work on a poster that highlights their collective and individual learning journey including personal learning goals, interpretation of project objectives and planned individual contribution. The whole team works together in Semester 1 to creatively design an image processing system that can be used to address climate change challenges: contextualising

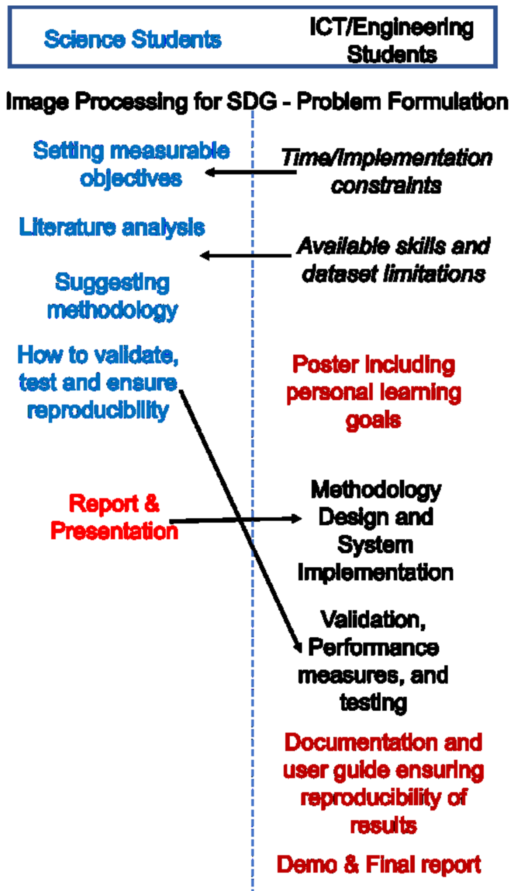

Figure 1: Project timeline and responsibility.

SDG challenges, identifying the problem, relate engineering system design theory and algorithms covered in the class, and propose specific system design approaches that can be used.

At the end of Semester 1, science students deliver an oral 5-min long presentation, when they are assessed on clarity of the slides and delivery, technical appreciation, and response to questions. The students also submit a group technical report, which is assessed based on the clarity of objectives, whether the project is put well in the context of image processing systems for climate change, if the methodology is sound in terms of providing a convincing image processing solution, the depth and breadth of the literature review, suggestions to ensure reproducibility, replicability and interpretability of the results, and finally, the description of applications, future work and personal reflections. In Semester 2, engineering students continue alone with concretizing the methodological steps proposed and implementing, validating and testing the system. They use the report produced by the science students as a guide in selecting and fine-tuning methodology. At the end, the students produce a technical report that is assessed in terms of the level at which the project objectives are met, soundness of the methodology, appropriateness of implementation, experimental setup, including data acquisition, validation (justification of the metrics used) and analysis. The final outcome must be reproducible. The students submit one report per group together with the running code and user guide. They also give a short presentation where they demo their work.

The formative feedback is given throughout the semesters during dedicated workshop sessions where each team shares their current progress and discusses open issues, and has opportunity to ask questions. The summative feedback is provided after each piece of assessment. Figure 1 summarises the overall approach highlighting the submitted pieces of assessment.

3.2 Case Study Two: Information Transmission and Security

In this assignment, implemented via a hybrid approach, group work was implemented through a cooperative learning group methodology, i.e., the instructional use of small groups to promote students working together to maximise their own and each other's learning. As discussed by Brame and Biel (2015), cooperative learning is a proven tool for promoting deep understanding of content and building particular transferable skills. A particular transferable skill being explored here was the ability to relate specialist technical content to the broader UN SDGs. A formal cooperative learning approach was adopted whereby the instructor defined the learning objective, communicating criteria for success, playing an active role during the groups' work, monitoring and evaluating group and individual performance. Individuals within the group work together to identify and describe individual building blocks of a digital communications system for the

Table 1: Group and peer assessment criteria

Production	Technical content	Delivery
Has the group made appropriate balance, use of text, visuals, animation, diagrams, slides?	*Has the topic been covered in suitable depth & accuracy with an appropriate level of technical detail?*	*Does the lesson have a logical structure?*
Is image and audio quality satisfactory?	*Does the video show a sufficient level of technical appreciation & understanding?*	*Did all members contribute to narration?*
Is the video appropriate for an audience comprising those with a background	*Does the video show a sufficient level of technical appreciation?*	*Does the video lesson have good cadence, flow and rhythm?*
Is there consistency in quality of production throughout?	*Is there consistency in the quality of technical content throughout?*	*Is the use of language and (technical) vocabulary appropriate and effective?*
Does the video run to time?	*Did you learn something that you did not already know?*	*Is there consistency in quality of delivery throughout?*

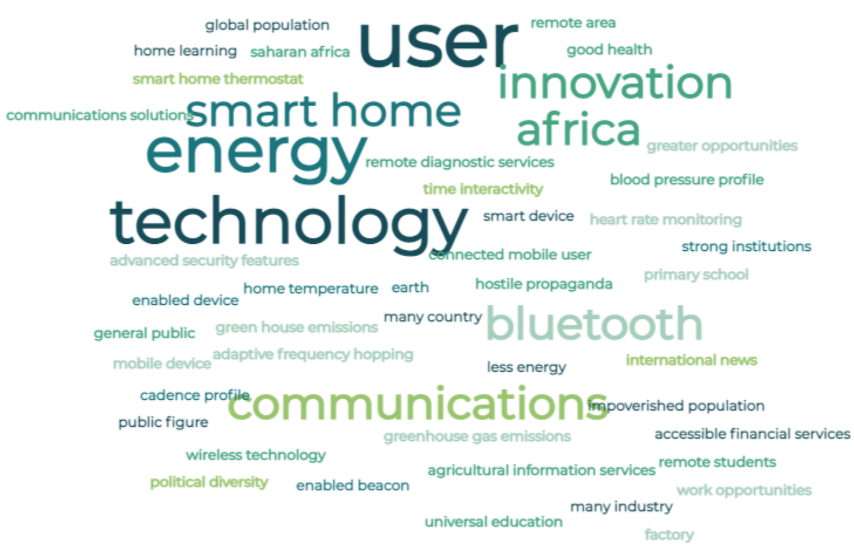

Figure 2: Student keywords linking digital communications technologies to SDGs.

standard they were researching, and how this could be leveraged to tackle the UN SDGs. Every individual was responsible for understanding all aspects, and submitting one 5-min video per group at the end of the assignment. While introducing the group's task in class, the instructor discussed the criteria, published on Myplace, for group assessment, peer assessment and individual assessment. Each group was assessed by the instructor and peer assessed by all individuals from other groups with 3 criteria: production, technical content and delivery. These criteria were further broken down into sub-criteria as shown in Table 1 below. Each sub-criterion was assessed by instructor and by peers, with: Yes (2 marks), Partially (1 mark) or No (0 marks). The instructor double weighted the mark for technical content. Individuals were encouraged, by rewarding them with one mark for each group video assessed, to participate in the peer review process (having watched the produced video in their own time) to be able to understand how theory meets practice through different technical standards. Individual contribution within a group was also assessed by peers within the group, weighting the individual contribution accordingly.

The instructor observed group interactions and progress in class every week by circulating between groups during the half an hour dedicated to cooperative group work during in-person sessions on campus. When problems were identified, the instructor intervened to guide students to move forward on the task and work together effectively. A number of digital communications standards were provided to the students to choose from and explore. Some relevant keywords from group videos are included in Figure 2, with respect to relevance of standards to UN SDGs 2, 3, 4, 5, 7, 8, 9, 12,13,16 and sustainability. Figure 2 shows a good contextual grasp of linking theory to pertinent problems relating to sustainable development goals.

4. STUDENT FEEDBACK ANALYSIS

4.1 Case Study One: Image and Video Processing Class

Image and Video Processing projects were undertaken by seven student groups. The students proposed a range of topics including automatic waste recycling, monitoring the intensity of deforestation, identifying changes in the shape and size of glaciers, assessing the changes in Amazon rainforest, and monitoring the health of bee population. After submission of all pieces of assessment, the students were asked to anonymously provide qualitative and quantitative feedback. Specifically, the following questions were asked:

Q1. What did you like and what dislike related to how the project work was organised?
Q2. Which part of the project work you liked/disliked the most?
Q3. Did you enjoy working in the team in Semester 1 and Semester 2?
Q4. Do you feel that the project work supported your learning?
Q5. What would you change next year?
Q6. The project was a good opportunity to develop practical image processing skills.
Q7. I enjoyed working on the project.
Q8. I feel I improved my team work abilities after the project.
Q9. The project challenge me to think creatively.
Q10. I enjoyed working in a multi-disciplinary team addressing climate change problems.

Questions (Q) 1-5 require descriptive response to capture qualitative feedback, while Q6-10 are yes/partly/no questions to quantitatively capture student satisfaction. Close to 30% of students filled the online questionnaire. Figure 3 presents a word cloud obtained from the responses to Q1-5, where words such as free, practice, researching, team working, enjoyed, experience, ideas indicate positive views towards practical problem-solving collective work, that allows free choice of topic. Further insights from the qualitative feedback are: (1) the students generally enjoyed working collectively and were happy with open-ended climate change projects, where they are free to choose a topic that is close to them; (2) two students thought that more support was needed; (3) one student pointed out a knowledge gap within the groups; (4) the students enjoyed the practical aspect of the project; however, one engineering student disliked the fact that science students were driving the topic selection; (5) the students felt that the project supported their learning, enabling them to apply techniques learnt in class to important climate change problems. These conclusions are in line with the quantitative feedback shown in Figure 4. The students enjoyed working on the project, which challenges their creativity and was a good opportunity to apply image processing skills to solve relevant climate change problems. But there was some dissatisfaction in terms of (interdisciplinary) team work, which could be partly due to the fact that the teaching was delivered online, and many science students were not physically located in Glasgow. This issue might have been partly mitigated with face-to-face activities.

Figure 3: A word cloud from the received responses to Q1-5.

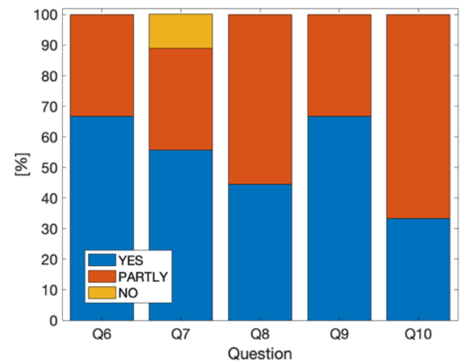

Figure 4: Quantitative student feedback to Qs 6-10.

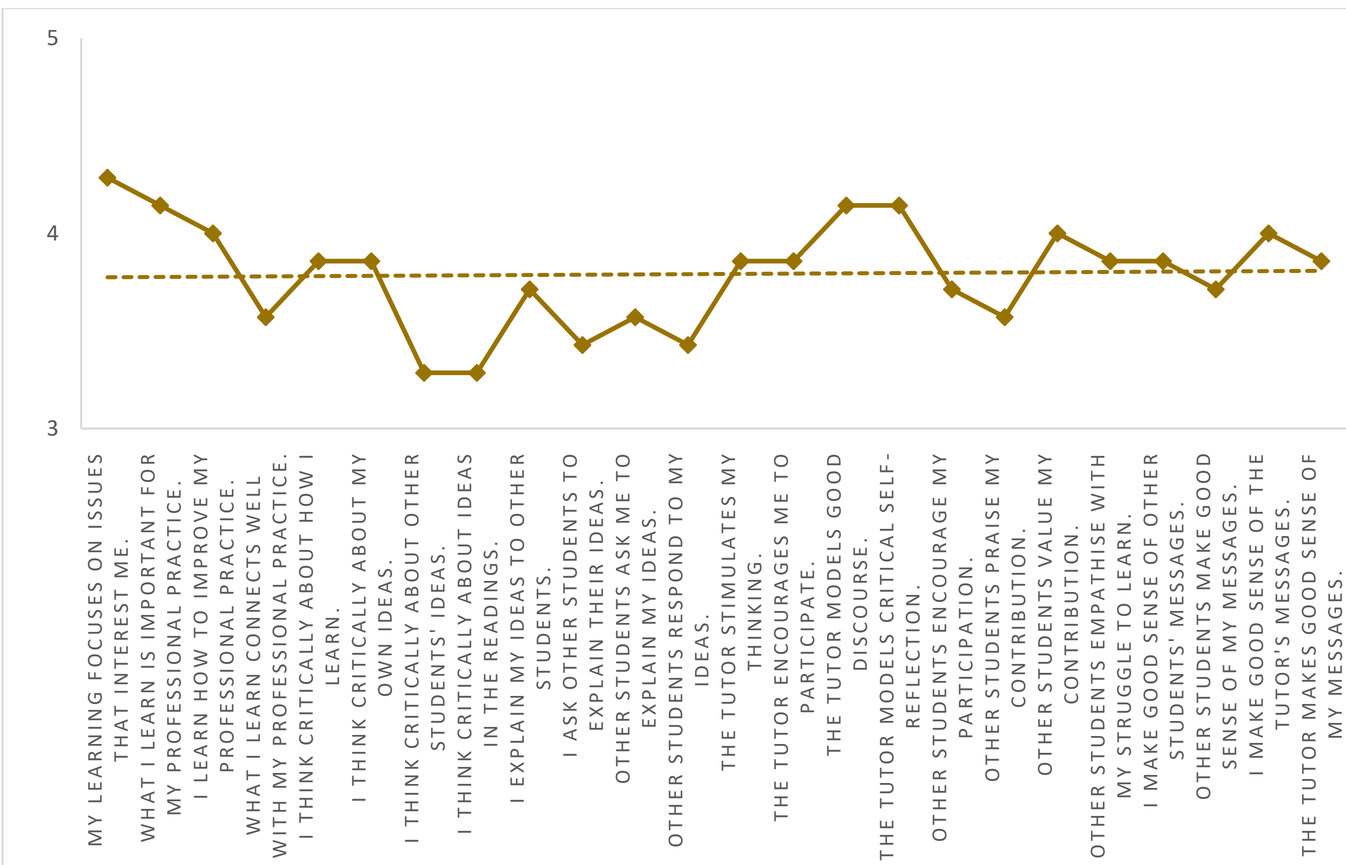

Figure 5: Self-reflection survey, showing average response for each of the 24 questions.

4.2 Case Study Two: Information Transmission and Security Class

The instructor encouraged reflection about how hybrid delivery of the module, including the group assignment, enabled the student learning journey. This was implemented via a self-reflection survey, provided by MyPlace, to be filled at the end of the module. 24 questions were asked with responses in the range: Almost never (1), Seldom (2), Sometimes (3), Often (4), Almost always (5). Figure 5 shows the average from all respondents for each question. Both tutor support, reflective thinking and interpretation-related questions were rated as most beneficial for learning.

5. CONCLUSIONS

This practice paper describes embedding of sustainability goals in engineering teaching curricula through open-ended group projects. The aim was to develop competences identified by UNESCO as essential to meeting SDGs (UNESCO, 2017), including critical thinking, integrated problem solving, and collaboration, as well as developing appreciation towards sustainable practices. The implemented approach shows high student satisfaction stemming from transferring knowledge gained in the course to solve important real-world problems. Group work and diverse teaching environment bring their own challenges, which was explored further to increase the breath of project activities. Some students expressed dissatisfaction with interdisciplinary group work. Therefore, future work will focus on designing interdisciplinary group work to better bridge the gap in background knowledge, skills and technical language used in different disciplines, especially since climate change needs collective input from multiple disciplines.

6. REFERENCES

Annan-Diab, F., Molinari, C. 2017. Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *Int. J. Manag.t Edu.*, *15*(2), 73-83.

Brame, C.J. & Biel, R. 2015. Setting up and facilitating group work: Using cooperative learning groups effectively. Vanderbilt University Center for Teaching. URL: http://cft.vanderbilt.edu/guides-sub-pages/setting-up-and-facilitating-group-work-using-cooperative-learning-groups-effectively/.

Chang, Y. C., & Lien, H. L. 2020. Mapping course sustainability by embedding the SDGS inventory into the university curriculum: A case study from national university of Kaohsiung in Taiwan. *Sustainability*, *12*(10), 4274.

Ely, A. et al. 2020. Structured collaboration across a transformative knowledge network—Learning across disciplines, cultures and contexts? *Sustainability*, 12, 2499.

Gil-Doménech, D. et al. (2021) Integrating Sustainability in the Business Administration and Management Curriculum: A Sustainability Competencies Map. *Sustainability*, 13, 9458.

Sanchez-Carracedo, F., et. al, 2021, Tools for Embedding and Assessing Sustainable Development Goals in Engineering Education. *Sustainability* 13.21 (2021): 12154.

SDGAccord. URL: https://www.sdgaccord.org

THE: URL: https://www.timeshighereducation.com/rankings/impact/2020/

UNESCO, 2017. Education for Sustainable Development Goals: Learning Objectives. *Technical Report.* URL https://unesdoc.unesco.org/ark:/48223/pf0000247444 (accessed on 23 May 2022).

United Nations, 2015 Transforming Our World: The 2030 Agenda for Sustainable Development. *Report*. URL: https://undocs.org/en/A/RES/70/1 (accessed on 23 May 2022).

Willott, J., 2009. Embedding climate change in the curriculum. *China and Global Climate Change*, Lingnan University, Hong Kong, 18-19 June 2009 (pp. 582-595).

Yáñez, S. et al. (2019) The sustainability report as an essential tool for the holistic and strategic vision of higher education institutions. *Journal of Cleaner Production*, *207*, 57-66.