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# LEARNING SUSTAINABLE DEVELOPMENT GOALS IN CHEMISTRY LABORATORY PRACTICALS

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## Abstract

Our society is heading towards sustainable development. At the core of the 2030 Agenda for Sustainable Development are 17 Sustainable Development Goals (SDGs). SDGs describe major development challenges for humanity (e.g. end of poverty and hunger, quality education, ensure availability and sustainable management of water, the achievement of sustainable consumption and production patterns, combat climate change and its impacts, build peaceful and inclusive societies). For the SDGs to be reached, everyone needs to do their part. By changing our habits and making choices that have less harmful effects on the environment, we have the power to build a more sustainable world. Universities can play a relevant role in achieving the SDGs, since they are important agents for the integral development of future citizens, equipping the next generations with the skills, knowledge and motivation to address the challenges and opportunities of sustainability in increasingly complex and global contexts. Chemistry laboratories at Universities can play an essential role in helping society to achieve the SDGs. Students can understand and minimize the environmental impact when working in the laboratory and become aware of their role in achieving the SDGs. In order to check their knowledge of SDGs, the first-year students passed a test at the beginning of the practicals and another test at the end of them. The second test was answered by 75% of the students, and the results indicated that all of them know the main purpose of SDGs and that each can contribute to achieving the SDGs. In a four-point Likert scale, 85% of the students indicated that after finishing the chemistry practicals course, their awareness about the importance of properly handling chemical residues had increased to a great extent and 15% somewhat. In addition, after the laboratory sessions, 67.5% of the students answered that had considered the need to save tap and distilled water to a great extent during those sessions, and 32.5% somewhat. Finally, 82.5% of the students answered that they were willing to get involved in achieving the SDGs at the University through the actions prepared by teachers. Some students pointed out that the information provided in the laboratory sessions was their first approximation to the SDGs and expressed that is crucial the University's support for the implementation of the SDGs in the disciplines of the curriculum.

Keywords: Sustainable development, SDG, chemistry laboratory, laboratory practicals, Higher Education, University.

## 1 INTRODUCTION

Our society is moving towards sustainable development. The concept of sustainable development was defined by the World Commission on Environment and Development through its Brundtland report, entitled "Our Common Future". According to this report, sustainable development is one that must meet the needs of the current generation without damaging the capacity of future generations [1]. In 2015, the UN approved the 2030 Agenda on Sustainable Development, an opportunity for countries and their societies to embark upon a new path towards improving the lives of all, leaving no-one behind. The Agenda has 17 Sustainable Development Goals (SDGs). SDGs address the global challenges we are facing today, including the eradication of poverty and hunger; the fight against climate change and raising awareness to adapt and mitigate climate change; ensuring quality education and gender equality; and defence of the environment, amongst others. Each of the SDGs has specific targets that should be reached by 2030.

Chemistry plays an essential role in helping society reach these SDGs. The ACS (American Chemical Society) has identified seven priority SDGs and five additional SDGs that are fundamental to the work of the chemistry community. Recently, Axon and James [2] reviewed how sustainable chemistry can contribute to reaching SDGs from the point of view of the chemical industry (e.g. by optimizing resource efficiency and minimizing waste generated in existing and new synthetic routes; searching for alternative and less hazardous compounds; the application of catalysis and expertise in reusing, recycling and refining valuable metals).

As the United Nations indicates, to reach these goals everyone must do their bit: governments, the private sector, civil society and each individual. Universities can play a relevant role in reaching SDGs, since they are important agents for the well-rounded development of future citizens [3]-[6]. Thus, universities contribute to reaching SDGs by equipping future generations with the skills, knowledge and motivation needed to address the challenges and opportunities of sustainability in increasingly complex and global contexts [7], [8]. Universities can help students to become responsible and active citizens who will have a clear vision of future sustainability challenges. Education for sustainability aims to allow people to not only acquire and generate knowledge, but to encourage them to also reflect, from a responsible, global and future-oriented perspective, on the effects and complexity of the behaviour patterns of each individual and every group, and of decisions that they take.

Higher education is working to include SDGs in learning activities, academic projects, definitions of skills, courses, extracurricular activities, etc. [8], [9]-[13]. By way of example, the University of Nottingham Trent (United Kingdom), within the framework of its “Curriculum Refresh” programme, encourages the integration of one or more SDGs into the teaching and assessment of subjects in order for students to work on one or more SDGs [3].

A wide range of science curricula requires introductory college chemistry courses [14]. At many universities, General Chemistry is taken by a large number of students [14]. For example, at the Universitat Politècnica de València, introductory chemistry courses are taught on undergraduate courses in Environmental Science, Agricultural Engineering, Forest Engineering, Food Science and Technology, Biotechnology, Industrial Engineering, Energy Engineering, Aerospace Engineering, Mechanical Engineering, Electrical Engineering, Automatic and Industrial Engineering, and Electronic Engineering. There is, therefore, a potentially large number of students taking chemistry courses who may learn about sustainable development, and about SDGs and how these may be reached.

According to George et al. [15], many chemistry teachers aim to cover every aspect of foundational knowledge but many of the connections between chemistry topics and issues relevant to real-world applications cannot be included. They also suggest that teaching chemistry is also about including opportunities for students to visualize the practical application of concepts in chemistry to local and global economies, society, and the environment. For this reason, issues such as global food scarcity or the role of chemistry in polluting water resources should be included in chemistry courses.

Petillion et al. [16] introduced SDGs as a thematic framework in an introductory chemistry course. They used a systems-thinking approach to link SDGs to the course content, and used active learning activities that demonstrated the applicability of introductory concepts in chemistry to challenges associated with various societal, environmental, and global challenges. Specifically, they developed targeted case studies that apply concepts from groups of course topics within a single framing system that links to multiple SDGs. Some of those studies were related to chemical fuels, the enthalpy changes of chemical reactions and the ozone and CFCs.

Above all, chemistry laboratories can play an important role in reaching SDGs. Through performing small actions during laboratory sessions, students can become aware of their part in reaching SDGs.

In this study, we present different activities carried out with first-year students in general chemistry laboratory practicals to raise their awareness about reaching SDGs. We have worked mainly on SDG 6: Ensure access to water and sanitation for all; and SDG 12: Ensure sustainable consumption and production patterns. One of the targets of United Nations SDG 6 is, “By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally”. Sustainable consumption and production (SDG 12) is about doing more and better with less. It is also about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles. In order to introduce both goals to the students, the teacher provided information about them (Figure 1).

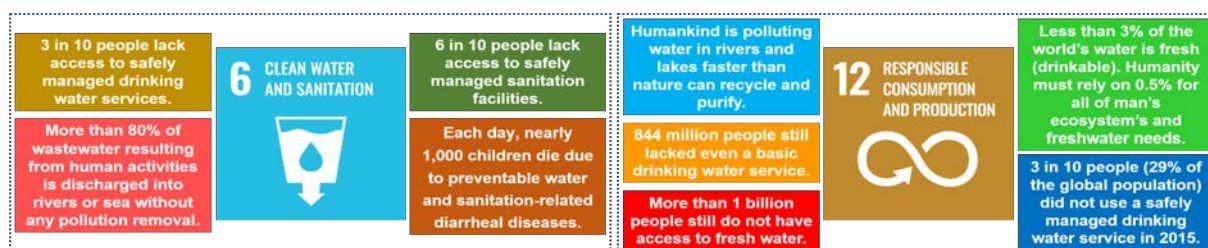


Figure 1. Data supporting the need to achieve SDGs 6 and 12 given to students. Source: [17], [18].

## 2 METHODOLOGY

The initiative was developed in laboratory practicals of three groups taking Chemistry through the medium of English in their first year of the Bachelor's Degree course in Aerospace Engineering at the Universitat Politècnica de València (UPV). A test in two parts was taken at the beginning of the first laboratory sessions. The first part contained a set of 10 multiple-choice questions about SDGs. Its purpose was to ascertain students' prior knowledge of SDGs. The test was published by Leiva-Brondo et al. [19]. In the second part of the test, the students were asked about their degree of commitment to taking action on different issues related to SDGs 6 and 12 (Box 1). This second part is the one analysed in this study. Questions were answered on a 4-point Likert scale (to a great extent, somewhat, very little, not at all). Before stating their degree of commitment, the students were informed about SDGs 6 and 12 (Figure 1). This test was taken by 51 students.

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*Box 1. Test related to SDGs 6 and 12.*

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In chemistry laboratory sessions, we will pay attention to small details to do our bit in caring for the Planet. Indicate your degree of commitment to what is indicated.

**To support SDG 6. Clean water and sanitation (for all):**

1. We will not pour reagents down the sink in order to not pollute the water.

**To support SDG 12. Ensure sustainable consumption and production patterns:**

2. During experiments and when cleaning materials, we will use only the needed amount of water in order to avoid wasting water. Tap water costs 1.91 €/m<sup>3</sup> and distilled water 90-1950 €/m<sup>3</sup>.

3. We will make an ecological use of paper.

4. We will not waste reagents.

5. These practicals are taught at times of greatest sunlight, therefore we may not need all the lights on.

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In the last practical session, students were told that they had a final test on SDGs, uploaded onto the PoliformaT (PoliformaT is the UPV's e-learning platform). The students were told that, like the first test, it would not count towards their results in this subject and was therefore voluntary. This second test consisted of 5 multiple-choice questions and 2 dichotomous questions (Box 2). This second test was taken by 41 students.

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*Box 2. Final test on SDGs.*

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1. The SDGs seek to:

a. Protect the planet and ensure prosperity for all.

b. Send humanitarian aid.

c. Assist war refugees.

d. Put an end to large corporations.

2. Can each of us contribute to reaching SDGs?

a. No, we need to do it through established plans.

b. Yes, through making small contributions like recycling.

c. Yes, with considerable financial contributions.

d. No, it is impossible to participate.

3. Where did you place your disposed gloves?

a. In the rubbish bin    b. In a specific container

4. After completing your chemistry laboratory practicals, has your awareness about the importance of properly handling chemical residues increased?

a. To a Great Extent    b. Somewhat    c. Very Little    d. Not at All

5. Did you take into account the need to save tap water and distilled water during practicals?

a. To a Great Extent    b. Somewhat    c. Very Little    d. Not at All

6. Are you interested in how aviation supports the UN Sustainable Development Goals?

a. Yes                      b. No

7. Are you willing to get involved in reaching SDGs through activities prepared by teachers while you are at the University?

a. To a Great Extent    b. Somewhat    c. Very Little    d. Not at All

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### 3 RESULTS

Each student can take care of the planet and build a more sustainable world for all by changing habits and making choices that have fewer damaging effects on the environment. The UPV Chemistry Laboratories intend to minimize the environmental impact of laboratory sessions.

The analysis of the first part of the test taken by students on the first day of the laboratory sessions showed that they were partially informed about the SDGs (data not shown).

Regarding the second part of the first test, in which students stated their degree of commitment, the results were: a) in relation to saving tap and distilled water, and not wasting reagents, 96.1% indicated that their degree of commitment was to a great extent, and 3.9% somewhat; b) on making an ecological use of laboratory paper, 94.1% of the students indicated that their degree of commitment was to a great extent, and 5.9% somewhat; c) on the unnecessary use of electric light during hours of greater sunlight, 78.4% of the students indicated that their degree of commitment was to a great extent, 17.6% somewhat and 3.9% very little; d) on not throwing reagents or hazardous waste down the sink to avoid water contamination, 96.1% of the students indicated that their degree of commitment was to a great extent, 2% somewhat and 2% very little. From the start, the students showed great willingness to consider measures related to saving water, reagents and paper, and to avoiding throwing waste and reagents down the sink.

In the laboratory sessions, the lecturers emphasized promoting different activities related to SDGs 6 and 12. In Box 3, there are different items related to SDGs 6 and 12 worked on in the first laboratory sessions.

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*Box 3. Example of items worked on in the first laboratory sessions related to SDGs 6 and 12.*

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Laboratory session 1: Safety rules, Safety Data Sheets (SDS), preparation of solutions

- Waste management. Explain that all liquid or solid waste requiring special treatment must be deposited in a suitable container. This includes used gloves and paper, and excess reagents. Comment the Environmental policy of the University (e.g. environmental management system, materials consumption, waste management, water and energy consumption).
  - Importance of saving distilled water, tap water and of not wasting reagents. Lectures demonstrated how to properly clean lab glassware so as to save tap and distilled water. Discuss the cost of the energy needed for the production of distilled water.
  - Introduction to Safety Data Sheets. Explain that SDSs include information on how to dispose of hazardous reagents (e.g. do not discharge into drains or the environment; hazardous waste must not be mixed together with other waste or hazardous waste if this might entail a risk of pollution).
  - Management of hazardous waste: a) Solid NaOH: transfer any leftover NaOH into the waste acid-base container; do not throw down the sink, b) Hydrochloric acid 37%. Hazardous waste: dilute and flush; neutralization, dilution, disposal.
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Working on the activities collected in Box 3 guides the students to participate in reaching SDG target 6.3 specifically: “By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally”; and SDG target 12.4: “Achieving the environmentally sound management of chemicals and wastes, and reducing their release to minimize adverse impacts on human health and the environment”. Through these small actions, therefore, we can heighten students’ awareness of environmental issues.

The second test was answered by 41 students. They all answered the first two questions correctly. They knew that SDGs seek to protect the planet and ensure prosperity for all, and that each of us can contribute to reaching these goals. Regarding question 3, where to dispose of used gloves, 95.1% said in a specific container. All of the students, independently of their answer, received the following feedback: “At the University of Edinburgh, gloves are recycled in the School of Chemistry. Waste Management Officer Tim Calder comments that recycling the single-use gloves has been easy to implement because the staff and students here have been happy to do their bit. The School has recycled about 85 per cent of all its used laboratory gloves – amounting to 15 tonnes – since introducing a pioneering recycling scheme in late 2014. Disposed gloves are processed to make raw materials used for furniture, floor tiles and sports pitches” [20].

85% of the students answered that, after the chemistry practical course, their awareness about the importance of properly handling chemical residues had increased to a great extent, and 15% somewhat (question 4). 67.5% had considered the need to save tap and distilled water to a great extent during laboratory sessions, and 32.5% somewhat (question 5). All of the students, independently of their answer to question 4, received the following feedback: "Waste disposal recommendations for solid NaOH. Hazardous waste must be managed responsibly. All entities that store, transport or handle hazardous waste must take the necessary measures to prevent risks of pollution or damage to people or animals. The waste must not be landfilled together with household waste. It should be recycled/reused, diluted and neutralized" [21]. Before answering question 5, the students read the following text: "Access to water is a human right. Many countries are facing ever-greater challenges linked to water scarcity, water pollution, degraded water-related ecosystems and cooperation over transboundary water basins. Water scarcity affects more than 40 per cent of the global population and is projected to rise. In 2017, an estimated 3 billion people worldwide lacked the ability to safely wash their hands at home – one of the cheapest, easiest and most effective ways to prevent the spread of diseases like coronavirus. Water availability is becoming less predictable in many places. In some regions, droughts are exacerbating water scarcity, thereby negatively impacting people's health and productivity, as well as threatening sustainable development and biodiversity worldwide" [22], [23].

As the test was prepared for students of the Bachelor's Degree course in Aerospace Engineering, we included question 6: "Are you interested in how aviation supports the UN Sustainable Development Goals?". The answer was affirmative for 92.7% of the students. The students received feedback related to SDG 6: "For SDG 6: Ensure availability and sustainable management of water and sanitation for all", some examples would be: New 'dry wash' techniques for aircraft can reduce the use of water by 95% compared to traditional cleaning methods. Emirates Airlines use a 'drywash' technique on its fleet which saves 11.7 million litres of water each year whilst improving the aerodynamic performance of its aircraft (reducing fuel burn). Oslo Airport conducts environmentally-friendly deicing operations by using non-toxic deicing fluid for aircraft and additive-free organic salt for the runways and taxiways" [24].

Finally, a large number of students (82.5%) showed interest in participating in activities prepared by teachers and geared towards reaching SDGs (question 7).

## 4 CONCLUSIONS

The teaching and learning of chemistry can play an important role in raising awareness of SDGs for the entire planet, and in demonstrating how we can all contribute to reaching these goals through taking action, however small. In the chemistry laboratory, different SDGs have been worked on with the students, especially those related to water pollution and responsible consumption and production. Through these activities, students' awareness of SDGs has been raised.

## ACKNOWLEDGEMENTS

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