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Pioneering the implementation of Sustainable Drainage Systems in engineering programmes from undergraduate to PhD: A journey from innocence to experience

Pionnier de la mise en œuvre de systèmes de drainage durables dans les programmes d'ingénierie du premier cycle au doctorat : Un voyage de l'innocence à l'expérience

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RÉSUMÉ

Les systèmes de drainage durables (SuDS) reçoivent une attention croissante de la part des chercheurs du monde entier en tant qu'éléments d'infrastructure verte qui contribuent à la transition des zones urbaines vers une gestion durable et résiliente des inondations. Cependant, l'enseignement dans les SuDS ne se développe pas parallèlement à l'expansion enregistrée dans la recherche, ce qui représente une lacune dans le domaine, tout en posant un besoin de développer et de délivrer des projets pédagogiques innovants pour transférer les connaissances acquises dans la pratique aux étudiants qui seront les futurs professionnels concevant, construire, exploiter et entretenir ces infrastructures. Cet article présente l'expérience acquise dans le cadre d'un projet d'innovation pédagogique à l'Université d'Oviedo depuis 2016-2017, intégrant SuDS dans le programme de plusieurs matières de programmes d'ingénierie de premier cycle, de maîtrise et de doctorat déjà existants. Dans ce but, ce nouveau programme a fourni aux étudiants une formation en SuDS d'un point de vue transdisciplinaire, en utilisant, entre autres, l'apprentissage par projet et les méthodes de classe inversée. Des critères et des indicateurs ont été développés pour évaluer l'impact du programme sur les étudiants et sa portée à travers plusieurs enquêtes. 291 étudiants ont suivi le programme au cours des 7 dernières saisons académiques, soulignant leur degré de satisfaction vis-à-vis de la formation reçue (92%), devenant les premiers ingénieurs civils et miniers spécialisés dans les SuDS, valorisant les compétences acquises à leurs programmes académiques.

ABSTRACT

Sustainable Drainage Systems (SuDS) receive an increasing attention from researchers across the world as green infrastructure elements that help transitioning urban areas towards sustainable and resilient flood management. However, education in SuDS is not growing alongside the expansion registered in research, representing a gap in the field, whilst posing a need to develop and deliver innovative teaching projects to transfer the knowledge acquired in practice to the students who will be the future professionals designing, constructing, operating, and maintaining these infrastructures. This article presents the experience gathered in a teaching innovation project at the University of Oviedo since 2016-2017, incorporating SuDS into the syllabus of several subjects from already existing undergraduate, master, and PhD engineering programmes. With this aim, this novel scheme provided the students with an education in SuDS from a transdisciplinary view, utilising project-based learning and flipped classroom methods, amongst others. Criteria and indicators were developed to assess the impact of the programme in the students and its outreach through several surveys. 291 students have taken the programme over the last 7 academic seasons, highlighting their degree of satisfaction with the education received (92%), becoming the first civil and mining engineers specialised in SuDS, adding value to the competences acquired through their academic programmes.

KEYWORDS

Amenity, BMP, LID, SCM, WSUD.

1 INTRODUCTION

Sustainable Drainage Systems (SuDS) are considered as key infrastructure elements to transition to sustainable urban flood management in the European Union (EU), where this paradigm shift is described mainly as local and slow-moving (Gimenez-Maranges et al. 2020). In consequence, SuDS have received considerable attention from researchers internationally as it can be checked in the scientific literature. However, innovation in higher-education about SuDS still is an underdeveloped area, which requires further observance and advancement. The lack of university programmes that transfer the knowledge acquired in practice and academic research in SuDS to education in this field builds a gap between the professional world and the students entering a challenging and varying working environment (Sañudo-Fontaneda et al. 2019).

Previous efforts found in the literature focused on low impact development (LID) techniques used a timeline comprising a semester, showing promising results when applying the project-based learning (PBL) methodology (Bradford & Drake, 2010). Another example on LID based on the hands-on approach is described in Ahn (2016). Finally, Liu et al. (2020) presented their long-term experience in landscape hydrology using LID techniques and the concept of sponge cities in China.

The teaching innovation programme presented in this paper introduces a novel approach combining already existing undergraduate, master, and PhD engineering programmes. With this aim, SuDS were incorporated into the syllabus of several subjects, seeking an education in them from a transdisciplinary perspective through the development of the learning outcomes and the acquisition of the competences from those subjects.

2 METHODOLOGY

2.1 Description of the teaching innovation programme scheme

The teaching innovation programme was launched in the 2016-2017 academic season. The scheme contained the following subjects from several engineering programmes following a potential timeline for a student taking the whole programme (Figure 1). This methodology uses already existing engineering programmes, implementing SuDS concepts of planning, design, construction, and maintenance transversally.

- **Undergraduate in Civil Engineering:** Graphic Expression in Engineering (Y-1), Topography (Y-2), Highway Engineering (Y-3), and Final Dissertation (Y-4). The final dissertation would be carried out in the 5th year if the students take the double degree pathway (Figure 1).
- **Master:** Digital Cartography, Urbanism and Land Planning (Y-5), Building and Civil Engineering Structures (Y-5), and Master Final Dissertation (Y-6).
- **PhD:** PhD thesis developed within the research line in “*Civil and Geoenvironmental Engineering*”, and more specifically in the sub-line in “*Biological and Environmental Engineering*”. The thesis might run for 2 - 4 years’ time. An extra 5th year could be added if developing the PhD under the part-time pathway.
- **Extension courses.** Short-duration specialised courses were provided each 2 years to complete the education in the topic, as well as opening the field to practitioners.

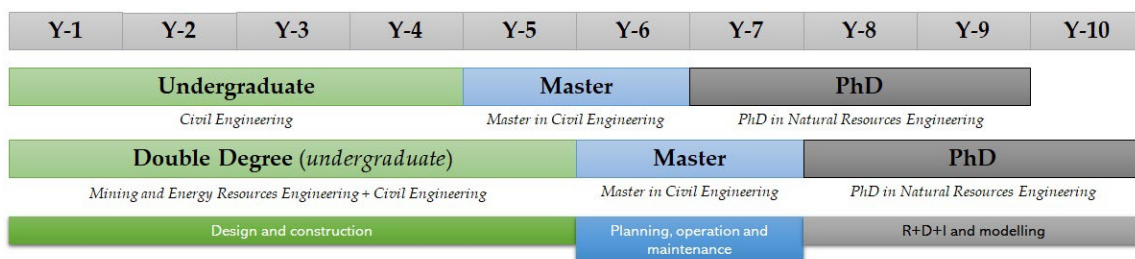


Figure 1. Time-scheme including the higher-education levels from the undergraduate to the PhD programmes.

A student entering the civil engineering programme and following the whole process might be completing it after 9 – 10 years, while a student commencing the double degree might need an extra year. If a student decides to leave the scheme after graduating from the undergraduate programme, he/she will have knowledge about design and construction. If the student completes the master programme afterwards, the competences will grow adding planning, operation, and maintenance. The PhD programme will provide research, development, and innovation (R+D+i) knowledge around SuDS, developing a comprehensive professional profile in SuDS when entering the job’s market.

2.2 Teaching methods and academic tools

The main teaching methods utilised in this programme are described as follows:

- **Project-based learning (PBL).** Real urban retrofit projects were used to implement SuDS. The main projects were the urban retrofits of the Avinguda Meridiana in Barcelona, and “La Mayacina” Park in Mieres (funded by the FEDER European programme), as well as Santuyano’s Boulevard in Oviedo.
- **Flipped classroom (FC).** A database was developed in the virtual campus of each subject, hosting key information for the students to consult before going into the classroom, so that the lecture could be focused on practical matters, increasing the student-lecturer interactions and problem-solving scenarios.

The academic tools considered to develop the abovementioned teaching methods are listed as follows: design, modelling, and planning software (e.g., Autodesk INVENTOR, AutoCAD, US EPA SWMM, QGIS, and Microsoft Project, amongst others); specialised conferences and workshops; teaching, gamification, management, and bibliographic tools; contact with key stakeholders; coordination strategy (a steering committee was created to support the coordination of the programme and the different academic levels, mainly focused in the undergraduate and postgraduate programmes).

Finally, an academic contest was organised to introduce external panels consisted of professionals to evaluate the group project covering the master level subjects. Also, the programme has a dissemination strategy divided into two main areas: academic and professional networks, and social networks.

2.3 Criteria and indicators

A range of criteria and indicators, highlighting student satisfaction, relevance in student’s access to the job’s market, and planning of the academic programme, amongst others, were developed with the goal to evaluate the impact of the programme between the students. A survey was launched to capture the perception from the students in that way.

At a second stage, a wider and more detailed survey with 30 questions based in the structural equation modelling (SEM) using the partial least squares (PLS) modelling through the SmartPLS presented by Sañudo-Fontaneda and Robina-Ramírez (2019), to grasp the social perception of SuDS, was launched within the wider academic community of the Polytechnic Engineering School of Mieres, University of Oviedo, with the goal to understand the insight about the outreach and future developments of the programme from lecturers and students.

In addition, data from industry was collected to check the interest on the teaching programme and how this could impact their future evolution as companies working around the water management cycle in urban areas.

3 RESULTS AND DISCUSSION

3.1 Academic outputs and social outreach

The programme has been taken by 291 students until the undergraduate stage, whilst 84 students finalised the first 2 levels (undergraduate + master’s degree) during the period 2016-2017 up to 2022-2023 (7 academic seasons). 43 students carried out their final dissertations in undergraduate programmes in SuDS, while 19 master students chose SuDS as their topic for their final dissertation. Also, 2 PhD students are about to complete the whole programme following the 9 years duration scheme showed in Figure 1. Three extension courses with participation of international lecturers specialised in SuDS have been given, being taken by 45 attendants.

The programme has benefited from the experience of universities and companies across the world such as Coventry University, North Carolina State University, University of Cantabria, University of Extremadura, University of Los Andes, the North Carolina Department of Environmental Quality, Barcelona City Council, San Sebastián City Council, Gijón City Council, Gijón Water Company, and the companies SUDS S.L., EXCADE S.L., and Pavitek S.L, as well as the Institution of Civil Engineers in Spain.

This teaching innovation project has highly contributed to the improvement of the academic profile of the University of Oviedo in the field, as well as its research outputs associated with it (e.g., 20 JCR publications, 15 research projects...), giving birth to a new specialised research group since 2017. The programme has captivated the attention from stakeholders such as city councils and water companies, as well as construction companies, which are employing students from the University of Oviedo since they received education about SuDS through

this programme, being highly valued by the industry.

3.2 Survey results

The original survey launched within the programme showed an increase in the marks obtained by the students in the different subjects, improving their degree of satisfaction with the education received up to 92%. All students pointed out that they will utilise the education provided by the programme in their professional life. In addition, the students highlighted the need for an expansion of the contents related with SuDS in the classes, showing eagerness to learn more about the topic.

This outcome led to a second and wider survey specially developed for the whole academic community in the School, receiving 66 responses in 2020. The outcomes from this survey emphasised the implementation of transversal subjects influenced positively the education in SuDS, the education in SuDS increases the identification of resources for their implementation, and the competences acquired in SuDS facilitates environmental awareness.

4 CONCLUSIONS AND FUTURE PATH

This teaching innovation project has contributed to implement SuDS in engineering programmes in Civil and Mining Engineering, adding value to the competences acquired by the students through their undergraduate programmes. Also, the scheme has provided the students in the master and PhD programmes with a higher level of specialisation in SuDS. The students from the University of Oviedo have become pioneers in the country, being the first in civil and mining engineers with education in SuDS and green infrastructure, developing a new professional profile.

This project adds knowledge to the field of SuDS in how teaching could benefit from research and vice versa, helping in the exploration of this journey from innocence and hopes, to experience and goals.

Furthermore, as this programme continues its path towards the future, a medium-term strategy has been established for the next years to come and is described as follows: (1) Completion of the full period of 9 - 10 years of the programme running continuously with the aim to reach the long-term stage and to capture the longitudinal evolution of the project as well as its outcomes and outreach; (2) Development of a tool to analyse medium and long-term impacts of this teaching innovation project using social perception methodologies; (3) Development of an international network of universities, companies, and social stakeholders to create a comprehensive postgraduate programme that responds to the challenges identified and the needs of education in SuDS provided by the experience from this teaching innovation project.

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