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Engagement capstone projects: a collaborative approach to a case study in Psychoacoustics

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Undergraduates in Spanish universities conclude their Bachelor of Science in Telecommunication Engineering with a capstone project. In recent years, students in technical degrees often postpone this last step due to an accelerated entry into the labour market or disappointment about the capstone project development. This article presents an approach which attempts to overcome these challenges: *Engagement* capstone projects. The authors, lecturers in two Spanish Universities (Universidad Politécnica de Madrid and Universidad Rey Juan Carlos, supported by the French Company, EOMYS, manage this educational project. Students become responsible for their contribution to a free, libre and open software project, which provides sound quality metrics based on psychoacoustics. They have the opportunity to work in a collaborative and international environment with industrial partners. The presentation of the technological platform shows the educational benefits of the employed tools: Python, GitHub and Jupyter Notebook. A student survey and the supervisors feedback supports an analysis, which helps improve the methodology as well as verify the benefits: better supervision, the development of social and professional skills, and useful community work. Finally, a couple of examples of *Engagement* capstone projects give insight into the results of this educational strategy.

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I. INTRODUCTION

In Spain, undergraduates have the opportunity to learn Acoustics in different University undergraduate degree programs. Among them, the Bachelor of Science (BSc) in Telecommunication Engineering (Electrical Engineering) with a major in Sound and Video might be the most comprehensive. The core subjects in this degree include Signal Theory and Communications, Electronics, Audio, Video and Video signal processing, as well as Acoustics. Since Spain joined the Bologna process to harmonise the European Higher Education Space among the different European countries, a final year project -hereafter referred to as capstone project (CP)- is a requirement in all Spanish universities to complete the BSc. studies. During this work, students shall apply the knowledge gathered during the BSc. courses, and this may deal with research issues or engineering practice. The duration of the CP might vary among universities and different degrees but it is normally between 6 and 18 European Credit Transfer System (ECTS) credits, being one ECTS credit equivalent to 27 hours of student work. This can be normally accomplished in one semester, although often it takes one year for some students (also depending on if they are simultaneously undertaking other courses). A duration in excess of a year is undesirable since it may result in student discouragement. The required workflow from the beginning to the end of the CP is as follows (with slight variations depending on the university): lecturers who are interested in carrying out a CP propose one or several topics. The students have access to the list of proposed topics once this is published and apply to those that are of interest to them (alternatively, a student could propose a topic to a lecturer). The lecturer receives the applications and the students are chosen based on their marks or previous experience in some courses. Once the lecturer (hereafter referred to as CP supervisor) and the student reach an agreement, then several steps shall be followed before CP completion. First, a short proposal is defined including CP title, scope, proposed tasks and expected time frame for project completion. This short proposal shall be made by the student, signed by the supervisor and approved by an internal commission. Once it is approved, the execution of the CP starts. When this is finished, the student must hand in a final project dissertation following the guidance given by the university and defend his work in front of a faculty committee consisting of three lecturers belonging to different departments. This defense is normally based on a short presentation followed by a round of questions/answers.

An excessive delay in the completion of the CP is detrimental for the student because it can block his entry to the labour market and also cause student give up. In some cases, students find a job without completing their CP, and they may develop their professional career in this situation. However, some companies ask for the university degree to hire and promote employees. Also, the degree might be legally required for the responsible Engineer of a project, to become a chartered Engineer and a civil servant. The CP supervisor supervises new students every year so it is important that former CP students finish on time to avoid the supervision of too many students at the same time. From the point of view of the university, delays are also not desirable because the number of graduates will be lower, leading to a poorer rate of success of the educational institution, as well as to extra administration costs.

Several difficulties have been reported by students that lead to significant delays in the project completion, especially in the CP execution stage. One reason is the lack of regular supervision during project execution. Students sometimes feel lost and overwhelmed by the project tasks they have to complete, and the resulting discouragement, in some cases, can lead them to drop out the project (Villamañe *et al.*, 2014). Often, the project scope is not respected or it is found to be too ambitious, resulting in a excessively long project execution, as was found in 39 % of CP students interviewed in (Villamañe *et al.*, 2014). Some students consider the CP as an intermediate step between their studies and the beginning of their professional life. They expect that the outcomes of the CP can be applied to their future jobs in the industry and also to acquire the necessary skills, these not being limited to technical ones. Examples are found about attempts to introduce the development by the student of different skills during the CP: capacity to incorporate a sustainability approach to the project (López *et al.*, 2014), teamwork development by suggesting CP where a set of 3 to 6 students have to find a solution to an engineering problem (Bordel *et al.*, 2019), or developing a framework of collaboration with companies that can help students to have first contact with a professional environment (Chand *et al.*, 2021).

This situation motivates the authors to propose a CP methodology that offers a more engaging framework for undergraduates and that addresses the issues described above as follows: offering to work on the development of specific tasks that are part of a larger project in a professional environment, collaborating with other students and academics but also professionals working in the industry, with a clear scope, periodic follow-up meetings, and using cutting edge programming language and technology. These can provide students with worthwhile and creative challenges that are useful for job hunting, an opportunity to develop skills beyond the theory and assurance that they will be supervised and have formative feedback by advisors.

This new approach to CPs, so-called *Engagement* CP, is being developed and applied by two lecturers from two the Spanish universities Universidad Politécnica de Madrid (UPM) and Universidad Rey Juan Carlos (URJC), along with the French engineering company EOMYS. EOMYS created a project in 2020 to implement Sound Quality (SQ) metrics written in Python, referred as to Modular Sound Quality Integrated Toolbox (MOSQITO)(San Millán-Castillo *et al.*, 2021). This is a collaborative environment in which anyone is invited to participate. Both MOSQITO and Python are Free Libre Open Source Software (FLOSS), so can be used free of charge. All these elements provide an excellent framework to *Engagement* CP, especially for topics applied to Psychoacoustics.

FLOSS provides an environment for sharing and advancing knowledge around the coding of certain algorithms. It is a current educational tool at university and it is often involved in the learning process (Bishop *et al.*, 2016). A well-known example of FLOSS used in education is Moodle. FLOSS has proven to be a valuable activity that help improve programming skills in Computer Science degrees such as experiments in subjects (Bishop *et al.*, 2016; Dougiamas and Taylor, 2003) or projects and CPs (Pereira, 2020). Moreover, (Hill *et al.*, 2011) states that there is strong evidence that community-based learning can enhance the quality of students work and support their employability. Some examples are found of FLOSS applied to Acoustics such as PyttA (Fonseca *et al.*, 2019) and PyEcholab (Wall *et al.*, 2018) in Python, and ITA in Matlab (Berzborn *et al.*, 2017), which are relevant and active projects. In this work, MOSQITO becomes the target FLOSS for educational activities.

The use of various programming languages is widely present in the teaching process in Acoustics. There are examples of educational tools supported by Matlab which give students an insight into theoretical and practical topics (Campbell *et al.*, 2005; Petculescu, 2017; Vignola *et al.*, 2014). However, Python is emerging as the *de facto* standard in scientific computing due to its advantages for general topics in Mathematics, Physics and Acoustics (Petculescu, 2017; Thomas and Christensen, 2014): contemporary problems of machine learning in Acoustics (Bianco *et al.*, 2019), or engaging practical issues as sound source location (Vivas *et al.*, 2017) and thermoacoustics (Ward *et al.*, 2008). Python is the language employed in this project to leverage its promising features in a learning environment.

Currently, Psychoacoustics is an active topic both in research and practitioners fields. SQ metrics are one of the crucial outcomes of that research. Many industries, for example automotive and aerospace, employ SQ metrics on a daily basis for noise, vibration and harshness (NVH) issues (Latorre-Iglesias *et al.*, 2016). On the other hand, fields such as Soundscapes (Pavón *et al.*, 2019) or Audio Analysis (Fan *et al.*, 2017; Moore, 2014) leverage SQ metrics to characterise sound signals. In addition, there is a considerable interest in standardisation (Deutsches Institut fur Normung E.V., 2009; International Organization for Standardization, 2017). Thus, CPs in Psychoacoustics seem to be appropriate for students' careers. This innovative educational project aims at developing SQ metrics algorithms by students in their CPs.

Other interesting proposals cope with Acoustics projects and management skills (Bös *et al.*, 2012), but to the best of the authors knowledge, it is the first time any CP shows this global and contemporary scope at University level. In addition, this CPs framework could be applied to other disciplines not only in Acoustics, but to any Engineering field.

The remainder of the article is organized as follows: section II, explains the learning proposal; section III, describes the technological platform; section IV, analyzes the first CPs; section VI suggests profiles for students and supervisors; section V shows some examples of CPs; section VII presents the conclusions of this approach.

II. THE LEARNING PROPOSAL

The *Engagement* CP proposal changes the regular procedures and features these principal steps:

1. Choice of a *turnkey* CP topic from an available and innovative range that may become a contribution to the FLOSS project: MOSQITO.

2. *Global* development of the CP assisted by a *selected* industrial supervisor and a *selected* academic supervisor.

3. Delivery of CP results, both in MOSQITO and in Academia.

The methodology of *Engagement* CPs is as followed: first, a SQ metric is chosen among those of interest for the MOSQITO project. At the very begining of the CP project, training on the basics of Github and how to contribute to MOSQITO is given by one of the employees of the industrial partner EOMYS, helping students to have smooth first contact with the involved tools, and to guide them to work according to the quality standards of MOSQITO. Regular follow up meetings are scheduled with the academic supervisor (each 15 days) and with both the academic and industrial supervisor (each month). In these meetings, supervisors provide guidance to the students and students must present what they have done since the previous meeting. Meetings are held in English, so students get used to work in an international environment. They can also ask for help or support from the different participants in the MOSQUITO community, giving visibility to their work. A private repository in Github is first created while having partial results and it is opened to the community when codes are finished and validated. Once the coding of the SQ metric is finished, the code is reviewed by both supervisors, with a requirement of successful validation using real signals. After these tasks, students must write a user manual using Jupyter Notebook to help the MOSQITO community to use their work. Students need to summarise and clarify the key points of their work and to think about how to efficiently present a blend of code and text explanations to the community. Hence, this methodology aims to show students all the relevant steps in a product development project.

Finally, a project thesis is required by the university to finish the *Engagement* CP. Nonetheless, a ready-to-use FLOSS contribution must be validated and included in MOSQITO, according to its coding and testing needs. Figure 1 presents a conceptual comparison between regular CPs and *Engagement* CPs, where differences with standard CP are highlighted graphically.

The choice of the *Engagement* CPs topics becomes an alternative to the standard procedure. Generally, in standard CPs, academic staff propose the project subjects. When it comes to research and state-of-art reviews, CPs work on partial problems or tasks which are linked to the academic staff research lines. These subjects are attractive for students but they normally miss a comprehensive scope of the research project. Often standard CP are focused only in technical skills but the majority of students need to develop transferable and social skills required by most of employers, as noted by (Healey *et al.*, 2013). Regarding engineering practice or simple product generation, projects remain of interest because they are applied topics. However, it is difficult to work on real engineering cases that will eventually be implemented due to lack of resources and tight university deadlines. Thus, the scope of common CPs may turn out to be somewhat incomplete from a practical perspective, which might frustrate students.

This novel approach proposes to overcome these issues and make topics both appealing and comprehensive to students. Psychoacoustics offers research and applied subjects, depending on the SQ metric and the student interests. Moreover, the design of *Engagement* CPs involves a *turnkey* contribution to MOSQITO, which is fully operative and validated. The *global* development of the project includes both engineering and social issues in a practical environment. The *Engagement* CP fallows students to solve Acoustics, signal processing, mathematics and computing problems. Additionally, and as added value, students deal with resource and time management, self-learning, and communication skills in an international environment. The *Engagement* CPs are permanently supervised by an engineer from industry and academic staff to fulfil the scope and development requirements.

A. Learning outcomes

The following list gathers the expected learning outcomes after completing *Engagement* CPs:

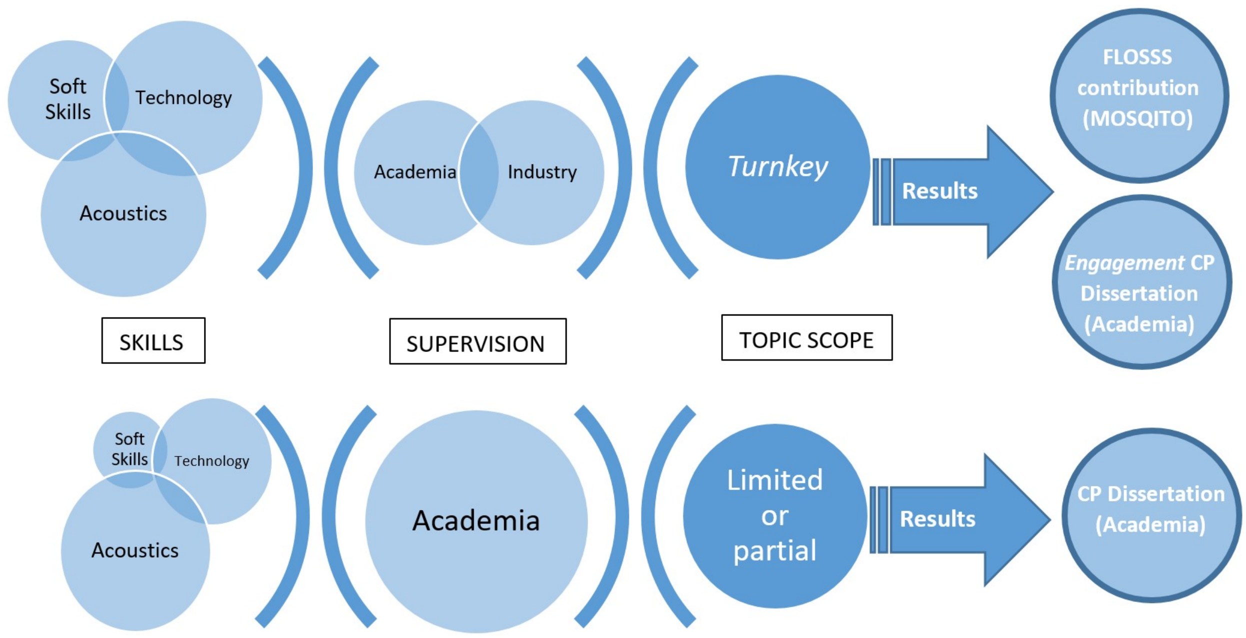


FIG. 1. Comparison of the classical and the *Engagement* CP approach. The relative size of circles represents the importance of the skills. Supervision differs as well as the topic scopes. Eventually, *Engagement* CP provides an additional outcome, which is the contribution to MOSQUITO. Up: conceptual map of *Engagement* CPs. Down: conceptual map of CPs (Color online).

- Technical learning outcomes:
  - Valuable training in Psychoacoustics and SQ metrics, as part of the work developed for the MOSQITO project.
  - Advanced technical analytical thinking resulting from hands on work, and not based on suitable commercial software.
  - FLOSS development, deployment procedures, and philosophy learning.
  - Experience on relevant and prevailing technologies such as Python, GitHub and Jupyter Notebook.

  - Knowledege about a product development cycle (in this case, a SQ metric) and a comprehensive scope that ends up with an operational and validated piece of software.

- Social and interpersonal skills outcomes:

  - Management of responsibilities on their tasks.
  - Enhancement of communication skills for meeting and presenting partial results, including English spoken.
  - Learning independent self-paced development, checking and searching for solutions in both their own code, and that of others.
  - Contribution to a worldwide community with a running FLOSS, which allows them to learn from professional feedback.
  - Empowerment of their early career, through their authored FLOSS. This practical experience is fully available for employers or other stakeholders.

III. TECHNOLOGICAL FRAMEWORK

The *Engagement* CPs methodology needs the right tools to achieve its goals. Traditional resources may not suit this approach because, in general, they run under a license fee and in local mode, not being so easily collaborative. The proposed project leans on: Python as the programming language; GitHub as the development, distribution, sharing and collaborative tool; and Jupyter Notebook as a platform to communicate projects and their tutorials.

A. Python

The use of Python suits the targets of *Engagement* CPs. Firstly, it is FLOSS and is available to everyone. It is developed under an OSI-approved open-source license and it is freely usable and distributable even for commercial use (Van Rossum *et al.*, 2007). Moreover, Python programming is manageable for undergraduates in UPM and URJC with a clean syntax that offers fast and easy-to-understand coding, and a wide range of useful libraries which are quickly and efficiently developed by an active FLOSS community (e.g. SciPy (Virtanen *et al.*, 2020) and Matplotlib (Hunter, 2007)). The Python libraries can help students with their algorithms in the basic tasks and lets them focus on the specific ones for their projects. Finally, there are countless high quality and free resources for developing and training, which might improve students hands-on learning on their own, when necessary.

B. GitHub

Github is a hosting platform for software development and version control based on Git. This tool becomes essential to follow-up in projects that involve several contributors. This FLOSS tool eases collaborative relations among students, supervisors, and the community. Everyone involved in the project can track changes in software and other documents, and compare them with previous versions without any loss of information.

GitHub works as the common repository of the *Engagement* CP, which is publicly available but with certain visualization and modification limitations to provide full control of the project. The structure of MOSQITO GitHub is available in this reference (MOS).

C. Jupyter Notebook

Every *Engagement* CP includes tutorials for all relevant code. Jupyter Notebook assists students with tutorials that integrates text and code. This is called *Literate Programming* and is a paradigm to help communicate algorithms by interleaving executable code, computation results and natural language text, which explains both codes and results (Pimentel *et al.*, 2019). Jupyter Notebook helps students learn communication skills by means of a FLOSS interactive support.

Reproducibility is relevant in these *Engagement* CPs because the achievement of useful and operational algorithms for the community is desired. To this end, Jupyter Notebook has been employed succesfully in a large number of scientific projects (Randles *et al.*, 2017). Thus, students leverage this tool to guarantee the validation of the work in their projects and to learn another worthwhile resource.

D. MOSQUITO structure

The MOSQITO project (MOS; San Millán-Castillo *et al.*, 2021) aims to provide a unified and modular framework of key SQ and psychoacoustics metrics, free and open-source, which supports reproducible testing for research, engineering and education. The MOSQITO project relies on Python, GitHub and Jupyter Notebook. MOSQITO aims to provide a collaborative and trustworthy development framework, which suit *Engagement* CPs educational goals. Github allows control of documents or code versions, making the participation of different contributors from academia and industry easy.

The scope of MOSQITO is publicly available (San Millán-Castillo *et al.*, 2021) and updated, which helps all project contributors work efficiently. The metric name, the reference standard or document for that metric, and the development stage are shown. Some of the more relevant SQ metrics are already validated, according to referenced literature (e.g Loudness for steady and non-stationary signals and Sharpness by Zwicker's methods (Deutsches Institut fur Normung E.V., 2009; International Organization for Standardization, 2017; Zwicker and Fastl, 2006)).

IV. ANALYSIS OF THE FIRST *ENGAGEMENT* CPS

This section presents an analysis of this learning proposal after working with some students. It is expected that the proposal would require an ongoing fine tuning depending on several factors. The evaluation of the benefits and drawbacks so far can help to build a lesson learned list, which helps improving the *Engagement* CP experience for future students. To support the analysis, on one hand, the point of view of the involved supervisors was collected (i.e. the authors so far). On the other hand, a survey was carried out comprising 24 students who have finished their CP in the last five years, from which 4 students were involved in *Engagement* CPs. The authors are aware that the sample is too limited to reach well founded conclusions, but they can at least show a trend of the achieved outcomes to date. Surveys of this kind are not usually required by Spanish Universities and supervisors, and alumni hardly stay in contact after their degree completion. From now on, the authors want to collect these data from other supervisors and increase the number of samples.

TABLE I. List of questions of the students survey to rate the satisfaction of standard and *Engagement* CPS in a Likert scale, including an short identifier for each one (ID). Questions were originally in Spanish, hereafter, they are translated into English.

ID	Question
Q1	How would you rate your CP experience generally?
Q2	How would you rate your CP supervision?
Q3	How would you rate your technical learning due to your CP?
Q4	How would you rate your social and interpersonal skills learning due to your CP?
Q5	How do you feel about your engagement with your CP?
Q6	How do you feel about the use of your CP results by other people?
Q7	How do you feel about the use of your CP results by sector companies?

Questions about the satisfaction with several aspects of the CPs were included in the survey, namely: supervision, skills acquired, student engagement, applicability of the learning outcomes to the future professional career and usability of the CP results by third parties. The questions are listed in Table I. The satisfaction was rated in a Likert scale from 1 to 5, being 1 'Very Dissatisfied' and 5 'Very Satisfied'. Figure 2 shows the survey results.

There were no significant differences in several of the items under evaluation between the students who participated in *Engagement* CPs and those who participated in standard CPs. For instance, students rated similarly their CP experiences as shown in Figure 2-Q1. However, some interesting differences were found. In this regard, Figure 2-Q2 shows that 73% of the students who carried out standard CP were very satisfied with the supervision received during project, while all the students who carried out an *Engagement* CP were very satisfied. This is one of the main expected improvements with this novel methodology, as regular follow-up meetings involving different participants are planned during the project execution.

The attitude towards the projects was significantly better from the supervisors' point of view. Frequently, students faced drawbacks confidently and tried to solve them. Hence, supervisors reported that the students commitment exceeded the average of projects. There was a typical starting-up excitement but, in contrast with regular CPs, this enthusiasm persisted up to the end of the work. However, the difference is not significant in the student's opinion according to their answers in Question 5 of the survey (see Figure 2-Q5) when they were asked about how they perceived their own commitment to the project.

From the very beginning, international meetings are held in the framework of the MOSQITO project, including the new students as standard members. Most of them reported a limited experience and are overwhelmed in their first steps. However, the evolution of their skills, both technical and professional, was remarkably successful according to supervisors. To date, students overcame different issues with a positive attitude and were assisted with proper mentoring. Thus, the involvement of students in the working group soon seemed to show positive results despite their initial weaknesses. In this regard, The survey reveals that students consider that *Engagement* CPs properly provide them with social and interpersonal skills. Figure 2-Q4 shows that all the students involved in a *Engagement* CPs were very satisfied with the transferable skills acquired during the project (i.e. communication skills to present their work, teamwork, deadlines management and use of English in professional situations), while just 60% of the students of standard CP chose this answer. These skills are expected to be useful for the entry of the student in the labour market and can be a differentiating factor in their CVs. However, students do not show significant differences regarding technical skills depending on the type of CP, as can inferred from Figure 2-Q3. Authors think that problem-solving skills and perseverance might be perceived as social skills by the students, although they can help improving their technical background.

The satisfaction with the perceived applicability of the learning outcomes to the student's future professional career was also higher for students involved in *Engagement* CPs, see Figure 2-Q7. In response to the question about the satisfaction with the link between the results achieved during the CP and the possible interest of the industry in them only 40% percent of the students who carried out standard CPs were very satisfied, while for students participating in *Engagement* CPs this percentage was 75%. In response to the question about if they considered that the results of the CP could be useful to other students, researchers or professionals, 75% of the *Engagement* CPs students were very satisfied, while for standard CPs only 50% of the students chose this answer, and 25% of them were neutral or disatisfied (see Figure 2-Q6). The *Engagement* CPs aims at strengthening the connection between what the students are accomplishing during their CPs and its applicability to the industry and academia. The goal is to improve students' perception about their work being useful and hence, to increase students' motivation and performance.

To date, *Engagement* CPs did not present relevant delays, procrastination or even quitting. Thus, it seems that *Engagement* proposals might be motivating enough to decrease students dissatisfaction with their CP. Regarding the first *Engagement* CPs, the results are promising within the limited number of available samples at the moment.

V. SUGGESTED PROFILES OF PARTICIPANTS IN *ENGAGEMENT* CPS PARTICIPANTS

From the academic supervisors' experience up to now, this section presents suggestions about the profiles both supervisors and students should have to complete a *Engagement* CPs successfully. The participants profiles should not necessarily be limited to the suggested profiles, but in the author's opinion this may help to avoid difficulties in the project execution.

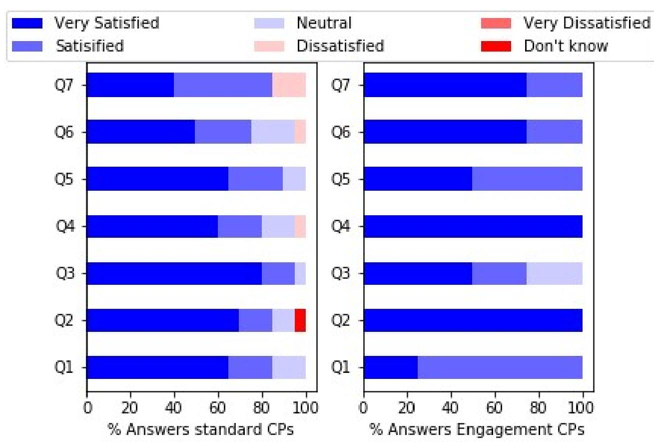


FIG. 2. Results of the students survey concerning CPs. Comparison between the percentage of answer for every question of standard CPs students, on the left, and *Engagement* CPs student, on the right. Questions are identified by their ID from Q1 (Question 1) to Q8. The Likert scale is represented by different colors. (Color online)

A. Supervisors profiles

Supervisors play a key role in the proper development of the *Engagement* CP as these projects require significant involvement on the supervisors' side. Firstly, *Engagement* CPs are challenging for supervisors because they are state-of-art projects. Sometimes the project deals with a recent research algorithm with no FLOSS or available track; other times, with SQ metrics that feature sparse specifications. Students often need more frequent follow-up meetings, and some extra assistance to manage uncertainty around the project. Supervisors must bear in mind the development of social and interpersonal skills. Academic supervisors tend to focus on technical facts but the *Engagement* CPs make this additional vision possible. The supervisors should provide the best-fit training or resources to fulfil students needs on these subjects.

Thus, the adequate supervisors should consider that managing *Engagement* CPs may need more involvement than expected in regular CPs. From the authors experience, the number of follow up meetings doubles, and the time devoted to students increases by 30% during *Engagement* CPs in comparison with traditional CPs supervised by the same lecturers. Besides, at least one of the supervising members must substantially manage Psychoacoustics and the other one, the programming toolkit. Additionally, the academic supervisors should have extended knowledge in social skills and professional background in their career to instill confidence in students. A lack of these skills between the two supervisors might lead to inappropriate student guidance. Students require outstanding and steady support because these projects become challenging in technological and managerial terms. Counting on an additional industrial supervisor helps manage these issues because the academic part is properly complemented.

The industrial partner EOMYS was exceptionally collaborative with students. This company provides students with initial training on the structure of MOSQUITO data and algorithms to facilitate students work. EOMYS promptly supports technical and programming issues within the development of the projects. Furthermore, EOMYS and the supervisors jointly assesses projects scopes and results. MOSQITO is FLOSS and all efforts are voluntary, which makes management on the industrial and the academic sides smooth. However, in other resources limited environments (e.g. projects with a tight deadline), the application of this type of CP might suffer from more intense discrepancies that need to be managed.

B. Students profiles

When supervisors and students have the first meeting to decide if a new *Engagement* CP will be started, supervisors must provide a clear explanation on the development of the work because not all students suit an *Engagement* CP. Otherwise, students may be frustrated in a short delay and the project may collapse.

Supervisors need a strong interest in the project but it could end up unsuccessfully when students do not comply with a certain profile. One important feature is a *growth mindset* (Dweck, 2017). Fixed-mindset students who only lean on talent and find issues everywhere are likely to fail. The *Engagement* CPs deal with uncertainty to some extent in the technical part and the student should manage it. In addition, students might lack management, communication or teamwork skills due to their limited experience and the provided environment may be intimidating to them.

For the moment, all *Engagement* CPs focus on undergraduates in Telecommunication Engineering, with a major in Sound and Video. These students should have enough programming skills to face FLOSS (i.e. Python, Github), even when they never coded within the project technological platform MOSQITO. Also, they should be experienced in acoustic signal processing. These skills are easy to find in this degree but it also should be checked, especially when students from other degrees may get involved.

Nevertheless, supervisors consider that missing skills can be achieved during the project. If students are shy when speaking up in a foreign language it may become an issue. Also, poor outcomes may be more likely where students are uncomfortable with teamwork and deadlines under pressure. These students are more suitable for other types of CP (e.g. research-based projects, case-based projects) that can be properly performed in their own and just with some assistance of supervisors. These interpersonal and social skills are a must to successfully tackle *Engagement* CPs. Ultimately, students felt that they had gained social and interpersonal skills after working working in *Engagement* CPs projects, as already commented in section IV.

VI. SOME EXAMPLES CPS AND THEIR RESULTS

This section includes the work of two relevant *engagement* CPs. All the code was developed according to the recommendations of MOSQITO and includes tutorials and validation of their calculations.

Supervisors, who are involved in MOSQITO, offered a clear explanation of the topic and the *Engagement* CP rules: motivation, project framework, expected technical and professional outcomes, delays, required minimum skills and skills to be developed. These two students decided to engage in their CP and eventually, ended up with two excellent *Engagement* CPs. The CPs were scored 10/10 plus Honours and 9.5/10 respectively. The faculty committee complimented students communication skills and the innovative approach at the CPs defense.

Example 1 Title: Psychoacoustic hearing model based on ECMA-418-2 standard (Jiménez-Carretero, 2021)

Several models offer solutions to loudness assessment, generally, for stationary signals. ECMA-418-2:2019 (ECMA International - European association for standardizing information and communication systems, 2019) presents a hearing model which suits both stationary and non-stationary signals. Additionally, this model allows the calculation of other metrics such as tonality or harshness. During this *Engagement* CP an algorithm that implements the ECMA 418-2 model was developed in Python, which became a new function of MOSQITO. The ECMA-418-2 hearing model was implemented by the student in different steps defined by this standard: middle and internal ear filtering, auditory filters bank, segmentation, half wave rectification, mean square value calculation, non-linearity and hearing threshold corrections. Once all these functions were correctly coded, the hearing model was validated. Figure 3 shows an example of the project outputs. The validation of the hearing model compares its equal loudness contours with those of ISO 226:2003 (International Organization for Standardization, 2003) standard. The final delivered software was found to have some discrepancies that could not be fixed due to a lack of information in the standard. Due to the satisfactory work of the student up to that moment, the *Engagement* CP finished. Both supervisors considered that the scope of the CP, as a learning activity, had been properly fulfilled in spite of the incomplete commissioning of the developed functions. Eventually, the MOSQITO community is currently helping improve the student contribution.

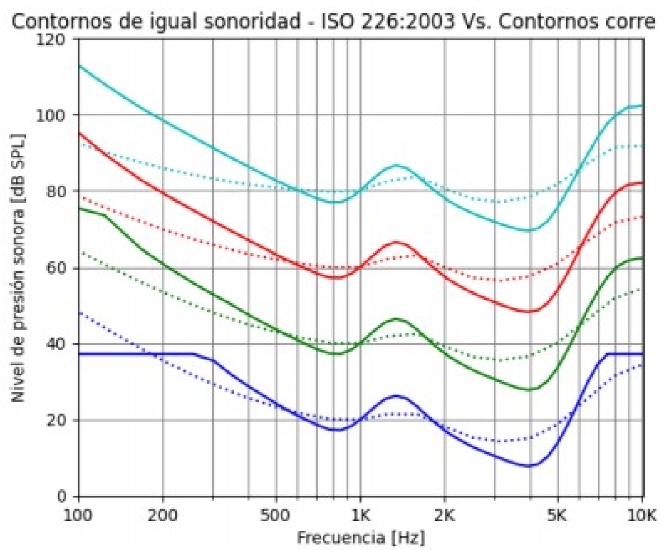
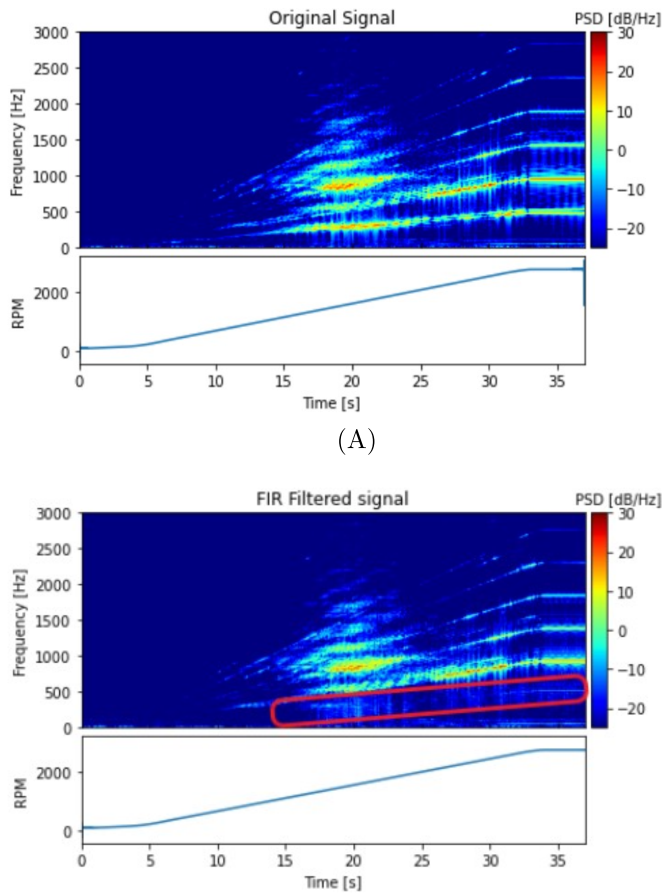


FIG. 3. Results of an *Engagement* CP (Example 1). Comparison of the equal-loudness contours from the reference standard ISO 226:2003 (International Organization for Standardization, 2003) (dotted lines) and the corrected hearing model of the ECMA-418-2 standard (solid lines), which are performed by the students algorithms. The y-axis represents the Sound Pressure Level in dB; the x-axis represents the Frequency in Hertz (Color online).

Example 2 Title: Time-varying filters for harmonics elimination (Álvarez-Jimeno, 2021) The aim of this CP was to implement a time-varying notch filter for harmonics elimination of a noise signal recorded during an electromagnetic motor acceleration ramp. It is then required that the filter cut-off frequency varies with the motor rotational speed. The idea behind the proposal of time-varying filters development was to use them to remove harmonics of real noise signals from electromagnetic motors and evaluate its impact on noise perception. Two different filter design strategies were used and assessed: Finite Impulse Response (FIR) and Infinite Impulse Response (IIR). The filter coefficients were chosen according to the required central frequency, bandwidth and frequency response. A range of filters, along with useful plotting tools, were integrated as new features in MOSQITO. This project was more challenging than expected due to the complexity of total harmonics elimination from a real signal. As the filter was applied by segments using windows, artifacts could be heard after its application due to the abrupt transition between one window and the next. Simple signals are treated properly but complex ones require fine-tuning of filters, which is to be developed in the next MOSQITO contribution. Figure 4 shows some results of this project.

The development of these two example projects was not seamless and some issues were faced by the students, which helps supervisors to improve the CP methodology for future projects, as reported in section V. Both supervisors and students felt comfortable and motivated all through the project. Some comments of the involved students revealed the innovative and enriching value of these *Engagement* CPs out of the classical approach, mixing-up professional, social and technical skills. These opinions agree with the discussed results of the students survey:

- Student 1: *"To develop my CP within MOSQITO allowed me to work on a real project in which I have been fortunate to collaborate with professionals in the sector and contribute to my work. Thanks to this, I experienced a typical workflow of a workplace,* *attending meetings and sharing my progress with the participants of the project. In the process, I learned to use cutting-edge technologies that will be useful throughout my career.The implemented standard lacks a number of details that made the development harder that expected"*



(A)

(B)

FIG. 4. (A) Results of an *Engagement* CP (Example 2). Evaluation of the performance of the time-varying filter authored by the student: Spectrogram and rpm of an original measured vibration signal of an accelerating motor. (B) First harmonic filtering of (A) by a FIR solution (Color online).

- Student 2: *" My experience within the project has been nothing but rewarding. It was clear to me from the beginning that my participation in MOSQITO would provide great* *insight into an international project collaboration. The implementation of the hearing model, described in Python, boosted my programming skills, as well as my knowledge in Acoustics. However, the project duration was too long"*

VII. CONCLUSION

The development of CPs currently presents some challenges that could lead Students to quit. Universities are concerned about this fact because the educational cycle would end up unfinished. Consequently, UPM and URJC think of different strategies that might help students with the last step in their degrees.

The proposed *Engagement* CP provides an innovative framework including Psychoacoustics, FLOSS and social and interpersonal skills development. Students become the principal role of their CPs and integrate themselves into a real working group. Hence, an industrial supervisor guides undergraduates along with an academic supervisor. Thanks to the collaboration with the French company EOMYS, the projects management provides hands on experience and introduces practical knowledge besides the theoretical knowledge that students learned in the classroom. Consequently, the learning outcomes and motivation exceeds that of standard CPs, and offers a balance between theory and professional skills, according to supervisors and the results of a students survey.

Furthermore, the contribution to a FLOSS project, MOSQITO, is attributable to the use of prevailing technological tools, like Python, GitHub and Jupiter Notebook. This means that students may be able to establish a digital footprint (in the form of Github contributions), which may prove attractive to students' future employers

However, some issues have been reported in this article and need to be improved, such as inappropriate students and supervisors profiles for *Engagement* CPs, and establishing suitable scopes of projects, to name the most relevant. An iterative feedback procedure will help fine tuning *Engagement* CPs and keep them aligned with the students focus. Nevertheless, EOMYS, UPM and URJC participants are satisfied with results so far and expect to continue, monitor and assess the *Engagement* CPs.

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