

Designing Eco-Feedback Systems for a University Campus

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ABSTRACT

This paper summarizes the results of an educational experience focused on the conceptual design of an eco-feedback system for a University Campus. The students participating to the study worked on the proposals of personal and public interfaces that were developed at the conceptual phase, starting from a set of compulsory and optional requirements. This work gives a summary about which were the requirements that were perceived as more important by the students and which were the most frequent proposals of interfaces and locations chosen for the deployment of them. The results of this work can represent a valuable guide for the design and deployment of eco-feedback interfaces in a public context.

CCS CONCEPTS

• **Human-centered computing** → **Interface design prototyping**; • **Social and professional topics** → **Sustainability**;

KEYWORDS

eco-feedback, design, education, guidelines, public environment

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1 INTRODUCTION

This work is a follow-up to the multidisciplinary workshop on eco-feedback [1] [3] held at the University of Toulouse in the Summer 2016, with the participation of 26 PhD students and colleagues of different Departments. The goal of the 2016 workshop was to focus on the design of eco-feedback systems for improving the environmental awareness of people inhabiting a University Campus and leading them to more energy conscious lifestyles [2]. The educational experience described in this paper, held at the Ca' Foscari University of Venice, builds on the analyses of the available literature on eco-feedback and on the results of the 2016 workshop and tries to overcome some limits, such as the lack of some design examples to start with or the reduced number of design proposals

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stemming from it. The availability of a larger number of students permitted to have a more statistically significant feedback about the preferred types of public and private interfaces and the locations for their delivery. We also considered a wider set of design requirements and we analyzed which were perceived as most important during the design phase. At the end of the design phase we asked the students to peer-review the project proposals and this gave additional feedback to discuss. The role of the students was two-fold: on one side they were young designers elaborating proposals starting from literature and from the examples of the previous workshop; on the other side they represented a relevant part of the stakeholders for which these projects were meant and for this reason their peer evaluations are particularly worth of consideration for further studies. The novel insights deriving from this study can be useful to the scientific community for promoting the design of eco-feedback systems for public spaces with a better impact on the stakeholders.

2 RELATED WORKS

While substantial benefits from the environment can come from the optimization of the infrastructures for the production and the delivery of energy [7], complementary advantages can come from the awareness of the environmental impact of the personal daily habits. Eco-feedback [1] [3] technology is based on this assumption and aims to provide feedback to people about the consequences for the environment of their lifestyle, for reducing energy consumption. Eco-feedback systems have been designed for public and private scenarios and for different classes of users. Their success is determined by different factors, among which the data presentation format can play a relevant role for attracting people and making them aware of the situation. While pragmatic visualization is often useful for giving accurate information, a complementary role for engaging and persuading people should be played by artistic visualization. As stated by Pierce et al. [12], both of them are necessary for satisfying communication needs. An engaging public installation was offered by the laser cloud in Helsinki [6], which represented energy consumption through light beams visualized in the city's sky. A more recent prototype based on a tangible interface visualizes the different sources of energy through colored vortexes, with the goal of letting the citizens to understand their balance for the different weather and use conditions [14]. Design proposals conceived for domestic scenarios range from abstract representations based on colour patterns, as the PowerSocket [5], to metaphorical representations, such as the 7000 oaks and counting project [6] that displays energy loads through a set of animated tree icons. Another proposal by Nisi et al. [9] takes advantage of artistic outdoor panoramas, trees, clouds and flowers for mapping data related to home energy consumption. Additional information, related to the personal behavior, can be given by a number of web apps. An example is the one developed by the Ca' Foscari University of Venice [16], that

calculates the carbon footprint on the basis of a survey related to the personal life style. Data sharing for triggering collaboration and positive competition mechanisms have been experimented both in domestic context, such as in the chalk-boards positioned on the house facades for displaying family data consumption to neighbors [8], and in public contexts, such as the public large screens of the EU FP 7 IDEAS Project [15].

3 THE EDUCATIONAL EXPERIENCE

The core of the educational experience was a half-day workshop, held at the University of Venice in the context of the HCI course for 80 undergraduate students in Computer Science. The workshop was preceded by a wide preparation activity, made mostly with collaborative remote learning methodology and meant to introduce the students to the concept of eco-feedback and to the related scientific bibliography. Scientific literature does not provide many examples for the design of eco-feedback systems in public context and this represented a difficulty for the 2016 workshop. Therefore, we shared with the Venice students the design materials of the 3 projects developed in the 2016 workshop (requirements, sketches, storyboards and videos where the groups explained the features of their project). These projects, fully described in [2], included both personal and public interfaces for the Campus of the University of Toulouse. The proposals included indoor and outdoor public artifacts: *Tree Totem* (based on a giant technological tree, smart flower-plots for the offices' tables and a smart-phone interface), *Hedgehog* (based on a giant hedgehog, some lower scale copies moving through the Campus and a smart-phone interface) and *Flower and Water* (based on a platform with interactive flowers, a colored multi-jet fountain and a personal bracelet). We asked a feedback to the students about these projects, asking them which features were more and less interesting. Besides we gave them the opportunity to propose additions to the list of the requirements used in the 2016 workshop and that derived from an extensive analysis of the eco-feedback literature [2]. The observations of the students led us to the extended list, split into seven categories (see Table 1) that was then used for the Venice workshop. The text presented in bold outlines the new requirements (i.e. req. 7, 8 and 19) or the shift from an optional to a compulsory state (i.e. requirements 13, 14, 15, 16 and 17). Aside from what was suggested by the students, the list features also a couple of requirements related to the monitoring of CO2 (req. 7 and 8), inserted following a suggestion of colleagues which are environmental scientists. As an additional example of eco-feedback application, we showed to the students the prototype of a mobile app, developed for the Venice Campus, for monitoring the consumption data of the buildings and sending feedback to the technical back-end [13]. All these materials were made available on Moodle and were discussed through extensive on-line chats. The final feedback of the students was collected through structured on-line surveys that then were elaborated by the supervisor of the course. Besides, before the workshop, we asked to each group to indicate, using shared Google Maps' landmarks, two possible locations for the public interface, accompanied by a brief explanation of their choices. During the half-day workshop, 20 working groups, starting from the materials described above, were asked to design their solution through collaborative discussion, using sketching

Table 1: Eco-feedback system (EFS): design requirements. The text in bold outlines req. added in the Venice workshop or changed from an optional to a compulsory state.

Data
1. The EFS has to present data related to power consumption, related to the whole Campus and to the single spatial entities.
2. The EFS may present power consumption data related to the single devices.
3. The EFS has to present production data related to the PV plant.
4. The EFS may compare power consumption and production.
5. The EFS may present water and gas consumption data.
6. The EFS may present data related to local fauna.
7. The EFS may present CO2 data related to Campus areas.
8. The EFS may present CO2 data related to the transportation means used by the Campus stakeholders.
9. The EFS may present crowd data.
10. The EFS has to present real time and back data.
11. The EFS may present additional data for attracting the stakeholders (e.g. room occupation, time and weather).
Visualization style
12. The EFS has to use at least two presentation styles; the numerical presentation style is compulsory, but other styles, such as graphical, metaphorical and analogical, can be used.
User profile
13. The EFS has to be adaptable to different profiles, including students, teachers, tech. personnel and cleaning/catering staff.
Deployment context
14. The EFS has to offer personal and public versions.
Input and output modalities
15. The EFS has to be multimodal, using two or more communication channels (e.g., visual, aural, tactile); it may involve the use of physical surfaces and objects.
Social features
16. The EFS has to stimulate collaboration for optimizing the resources and improving the Campus environment, using the skills that are proper to the different communities.
17. The EFS has to stimulate competition and engagement through communities, focusing on goals and rewards perceivable to users and compliant with sustainability.
Decor integration
18. The EFS should be perceived as part of the environment rather than being an ICT device.
19. The EFS doesn't have to use a lot of energy; the public devices should use renewable energy.

and low-fidelity prototyping techniques for expressing their ideas. We gave to each group felt-tip pens, cardboards, colored paper, adhesive tape, glue, scissors and modeling clay. The workshop was organized as follows:

- initial brainstorming (0.5 hours);
- sketching of the group proposal (1.5 hours);
- realization of the low-fidelity prototype (2 hours);
- delivery of the public interface on the selected Campus location (0.5 hours)

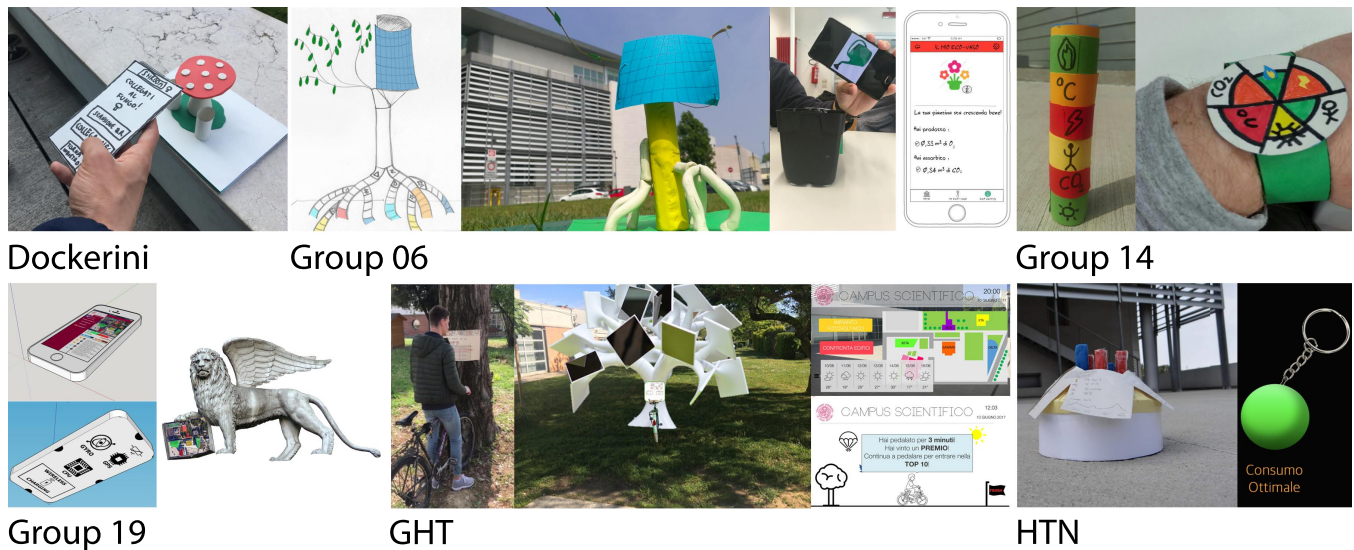


Figure 1: A selection of the best projects designed by the students.

After the end of the workshop the students were given a week for consolidating their proposals and delivering their work as: a written description; a checklist (that was cross-checked later by the teacher) specifying the compliance with the initial 19 design requirements; a set of narrative storyboards [4] based on sketches and photographs; a short video where the groups summarized the main features of their proposals. Besides, the groups were asked to add, on a new shared Google Maps representation, the landmarks representing the final installation sites. After the design phase, each student evaluated the proposals of two working groups randomly assigned. Overall, each group received 8 evaluations. The students evaluated the other proposals using the 6 parameters that, according to O'Brien [11], represent the engagement: ease of use, emotional involvement, cognitive involvement, aesthetics, degree of novelty, will to use the system again. While recent developments of the O'Brien approach describe a short version of the user engagement scale [10], at the time of the experiment, for the sake of simplicity, we based our work on 6 questions directly mapping the 6 parameters. Besides, we asked the students to rate the environmental sustainability of the proposal, the appropriateness of the deployment site and the smartness of the solution, defined as the intelligent use of resources. The scores were assigned using a 5-point Likert scale. Additional comments about the best and the worst features of the projects were collected using the Moodle survey tools.

4 RESULTS

Fig. 1 gives a glimpse of the best design solutions, according to the scores assigned in the students' peer-review.

4.1 Types of personal and public interfaces

As far as the design of the personal interfaces is concerned, most solutions (15 out of 20) were based on apps for smart-phones and 8 were based on smart-watches and smart-bands. Therefore 3 of them

used both types of devices. In a single case the smart-phone solution was coupled with a smart flower-plot, to be placed on the personal desks of the Campus. As far as the design of the public interface is concerned, most solutions (17 out of 20) took advantage of 3D tangible artifacts that, aside from some exceptions, had a big size for being perceived as landmarks. Touch interaction represented the input interaction that was used in most projects. Only 3 projects based their proposals on conventional flat touch screens.

4.2 Localization

As far as the localization of the public interfaces is concerned, there was a strong convergence towards outdoor locations. In detail: 19 groups out of 20 selected outdoor locations, 3 groups selected both indoor and outdoor location. It is interesting to note that most landmarks were not placed in front of the classrooms, but in the outdoor space that was perceived as the main square and in the surroundings of the two recreational spaces of the Campus. This choice was accompanied by the proposal of 3D artifacts (17 out of 20) whose shape resembled public landmarks (e.g. pillars, statues of animals that can be found in the institutional symbol of the region) or mimicked plants. In most cases the public interfaces were located in a single place; however in a few cases the groups proposed multiple locations. The answers related to the appropriateness of the locations confirmed the preference for outdoor locations characterized by frequent passages of people.

4.3 Compliance with requirements

Fig. 2 resumes the compliance with the design requirements, as assessed in the projects' *first draft* submitted one week after the workshop and in the *final project* delivered one month later. In this section we will focus mainly on the first draft, because in our opinion this gives a better idea of the themes that were perceived as more urgent by the students. Most groups complied with the compulsory requirements (see Fig. 2, marked with the capital C). In

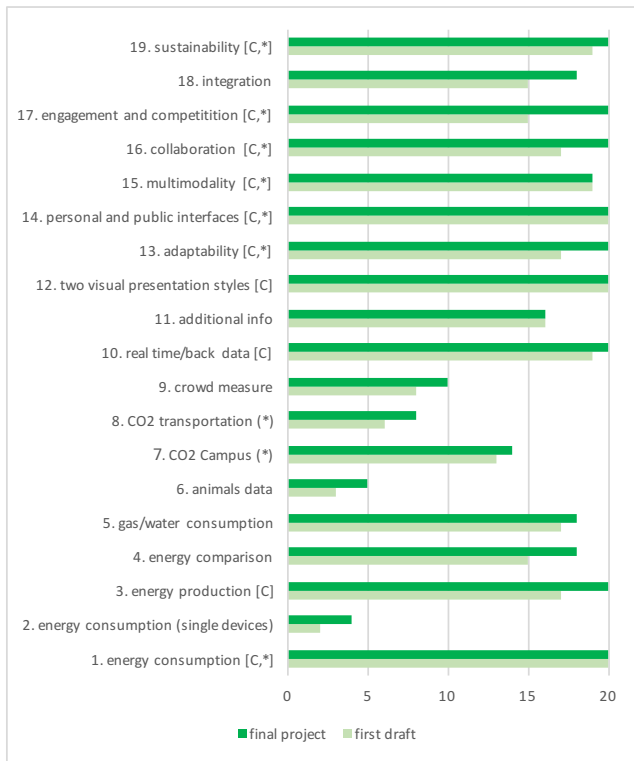


Figure 2: Compliance with the design requirements. The compulsory req. are marked with the capital C. The additional req. introduced for this experience are marked with the asterisk (*). The X axis displays the number of the projects (first draft and final project) complying with the design requirements.

particular, the adaptability, the collaborative features, the engagement and the competition, which were mentioned by the students as important requirements to add or to enhance after the exam of the 3 projects of the 2016 workshop, were considered in most proposals. However the presentation of CO2 data was perceived as less important, especially for what concerned the awareness of the increase of carbon dioxide for the different transportation means. The worst result was obtained for the representation of the consumption of the single devices: only 2 proposals out of 20 considered this requirement and in the final version of the projects the situation didn't improve too much. Besides, as for the 2016 workshop, the students didn't consider the presentation of data related to the local fauna as important for increasing their environmental awareness. Also the crowding of the different zones of the Campus was not considered worth to be investigated by most working groups (only 8 groups out of 20 considered this issue).

4.4 Engagement, smartness and environmental sustainability of the projects

Fig. 3, 4 and 5 resume the scores derived from the closed questions of the peer-review, based on a 5 points scale. Please note that in all the tables and figures we maintained the names chosen by each working

group. We used the Tukey box plot representation for showing the distribution of scores. For the sake of comprehension we split the results in three different figures: Fig. 3 and 4 represent all the parameters that concur to the definition of the engagement, while Fig. 5 represents the environmental sustainability, the smartness of the solution and the appropriateness of the location.

All the project proposals were considered easy to use, with median scores, indicated by a thick horizontal line placed inside or on the border of the colored boxes, equal or greater than 4.

The emotional engagement scored rather well, with all median values equal or greater than 3. GHT and HTN groups gained the best scores, with the second and third quartile above 4 (see Fig. 3, rows for GHT and HTN). As far as GHT is concerned, the students were engaged from the generation of energy through the bike that was part of the outdoor public interface and the associate competitive mechanism. As far as HTN is concerned, the students were engaged by the choice of a led key-chain for signaling information that then could be visualized in deep with the smart-phone and by the simplified architectural model, located in a place of passage, that could be touched for accessing information.

The cognitive involvement scored well, with median values equal or lower than 3 in most cases. The median was 4 and above only for Group 6 and Group 9. The proposal of Group 6 was judged as the most cognitively involving. As shown in Fig. 1, the proposal was based on a technological version of a plant (a mangrove) with photovoltaic plant and roots that showed information with color, a flower-plot for personal desks and the option to buy a special version of it for the home environment. The students in the answers to the open questions stated that the interface required a strong cognitive involvement because of the different modalities required for operating on it (i.e. through smart-phone and touch screen attached to the flower-plot) and the differences in the functionalities between the Campus and the home version of the flower-plot.

Aesthetics' median scores were usually above four (see Fig. 4), with the only exception of Group 12 and 17, which scored 2.5 and below. Dockerini and Group 6 (see Fig. 1) gained the best scores, with the second and third quartile above 4.5. The students focused mainly on the public interfaces, declaring that the giant mushroom and the mangrove plant were aesthetically pleasant. Also the plots placed on the desks were appreciated by the students for their aesthetic value.

The perceived degree of novelty varied, with most values equal or above 3. Only Group 12 and Group 17 scored lower. Group 19 and HTN (see Fig. 1) gained the best scores, with the second and third quartile above 4. As far as Group 19 is concerned, the students found novel the idea of designing the public interface as a landmark inspired to one of the symbols of the city (see Fig. 1); besides they found novel the idea of designing a cover with sensors embedded for collecting environmental data in the Campus and beyond. As far as HTN is concerned, the students mentioned again the led key-chain as a novel solution that could have been probably adopted by most students because it was cheap and ready to use.

Concerning the will to reuse the system, the results varied, with only Group 14, Group 19 and HTN placing the second quartile at 4. As far as Group 14 is concerned, the students underlined, for the smart-watch interface (see Fig. 1), that its simplicity, the clear and engaging display of information, the gesture based interaction

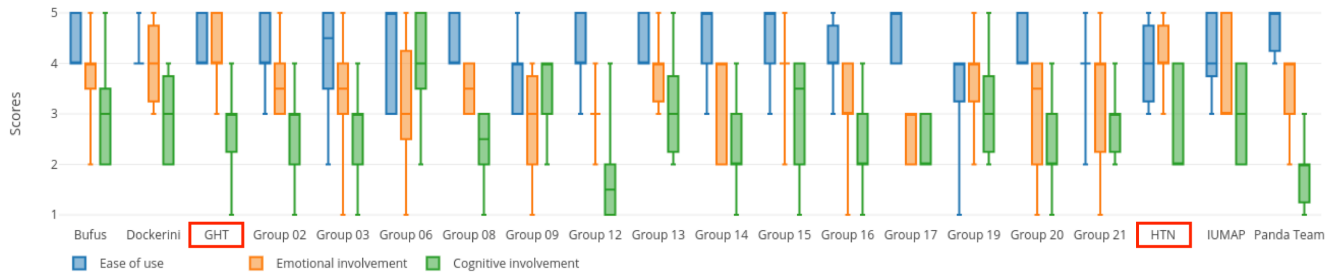


Figure 3: The first three parameters that define the engagement, evaluated by the students in the peer-review.

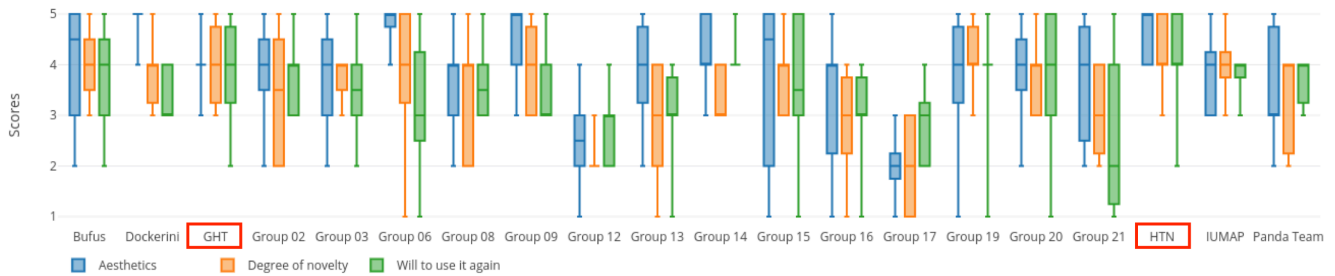


Figure 4: The second three parameters that define the engagement, evaluated by the students in the peer-review.

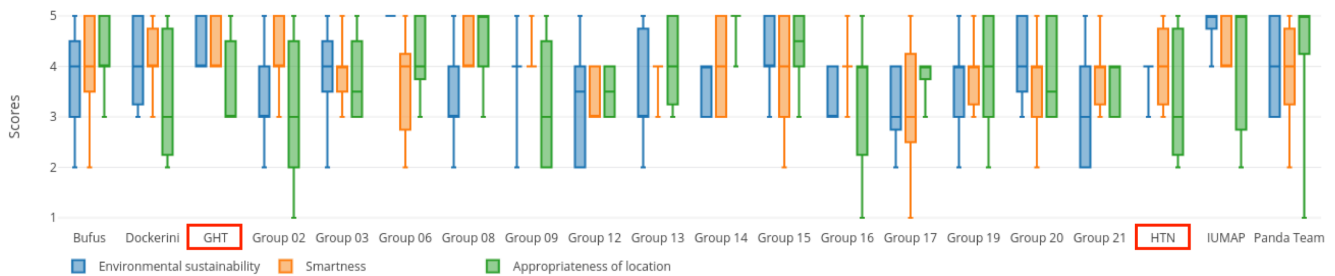


Figure 5: Env. sustainability, smartness and appropriateness of location, as evaluated by the students in the peer-review.

and the adaptivity to the user profile would have pushed users to use and reuse it. The simplicity was a feature that we already mentioned also for the led key-chain proposed by HTN.

The perceived environmental sustainability varied (see Fig. 5). Only in three cases (Group 12, Group 17 and Group 21) the second quartile was below 3. For GHT, Group 6, Group 15 and IUMAP the second quartile was equal or above 4. In all these projects the required power was given by photovoltaic panels that were part of the public installation.

The smartness of the solutions was specified in the questions as the ability of the solution to convey in an intelligent manner all the information related to the Campus. In all the cases the median value was equal or above 3. For eight groups the second quartile was equal or above 4.

We have already commented in Section 4.2 how the students perceived the locations selected for the delivery of the public interface. We would like only to add that Group 14 and Panda Team

were the groups which obtained the best scores (second quartile above 4) and that both projects had selected as outdoor location the surroundings of the main entrance of the Campus’ auditorium.

It is difficult to select the best one from all these proposals. However, looking at the performance for the different parameters examined so far, we tried to highlight the best proposals with red frames in Fig. 3, 4 and 5. HTN obtained the best scores for emotional engagement, novelty and will to reuse it again, with scores very near to the top results for the other parameters. Enlarging the analysis to the three parameters that were not part of the engagement definition (sustainability, localization, and smartness), the already mentioned GHT group emerges for what concerns the sustainability (adoption of photo-voltaic panels) and the smartness of the solution. The feature of these projects are of course worth to be considered for future developments of eco-feedback interfaces for a University Campus.

5 DISCUSSION AND CONCLUSION

A number of findings came from the study, resumed in this Section.

Identification of the favorite type of location for the public interfaces. The choice of the places for delivering the public interfaces outlined the preference for outdoor locations and for big landmarks, sometimes with a symbolic value (see the lion proposed by the Group 19, which obtained the best score for the novelty), placed where there were more frequent passages of people. The use of a shared map for collecting a feedback about the perception of space resulted to be a useful practice for accelerating the convergence towards the most relevant locations, and this was very useful in a situation where the spatial topology was different from the classic public square and therefore didn't make easy to understand what was perceived as the most meaningful part of the environment.

Identification of the requirements considered as most important. The analysis of the requirements considered by the students in their project revealed a coherence with the themes that the students asked to enforce or to add to the requirements of the 2106 workshop (requirements 1, 13, 14, 15, 16, 17 and 19). The students were less focused on proposing solutions for the requirements related to the CO₂ concentration, especially for that ones deriving from transportation. An hypothesis is that the students didn't value solutions that were displayed to them, such as carbon footprint calculators, because they didn't give a real time feedback about the consequence of the everyday actions (e.g. riding a bike instead of driving a car). This is coherent with previous research on eco-feedback [3] [5] which shows the positive impact of having a timely feedback about the personal behaviour. This should make reflect about the need, for future educational experiences, of focusing more explicitly on examples of devices capable of displaying CO₂ data in real time and relating them to human behaviour. Another interesting result is that the information about energy consumption brought at the granularity of the single device was not considered as important in a public context. This is an interesting difference compared to what stems from eco-feedback referred to a domestic scenario, where there are fewer devices that are under the direct control of the family and whose energy is paid by its members. The lack of interest for the animal life confirms the result of the 2016 workshop and it seems to assess the lack of an holistic view. Most projects were characterized an anthropocentric view where the main interest was for the dominant species.

Identification of preferences for specific types of public and private interfaces. The study confirms what already stemmed from the 2106 workshop: people are most prone to imagine fancy solutions for public (e.g. the technological tree with the embedded bike proposed by GHT, which gained the best score for engagement) than for private interfaces. The proposals for private interfaces displayed a preference for devices that are usually owned by the students or that are a complement to it (e.g. the cover with embedded sensors proposed by Group 19), with percentages that reflect the fact that the smart-phone is the most owned device and the smart-watches/smart-bands are a complement of growing importance. The personal interface that gained the best appreciation was based on another very popular personal object, the key-chain, whose led version proposed by HTN obtained the best score for

many parameters. An exception to this trend were the flower-plots (Group 6), which were probably influenced by the exam of the 2016 workshop proposals and that received a great appreciation from the peer-review. Besides, while the solutions that gained the best scores for the different parameters were characterized by low levels of cognitive involvement, this didn't prevent the peer-reviewers to assign high scores to the proposal of the Group 6, based on the mangrove, the smart-phone and the flower-plot, which was characterized by high levels of cognitive involvement.

Resuming, the work described in this paper can be valuable for further studies and design proposals related to eco-feedback systems for public environments, because it outlines practices (e.g. the use of shared maps for specifying the locations of the systems) and early guidelines (e.g. the preference for the type of the private and public interfaces) that can improve the effect of these systems. The identification of the requirements that were perceived as less important by the students, designers but also potential stakeholders, is another starting point for further investigation, targeted to understand how to improve the interest for the related issues. Further work will include the experimentation of the methodologies and the guidelines stemmed from this paper in the Campuses of the two Universities where we held the workshops, for validating them through the feedback of other students and improving their generality, with the final goal of coming to a generally applicable set of guidelines for eco-feedback in this kind of public contexts.

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