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# HCI and education: a blended design experience

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**Abstract** Teaching HCI in an undergraduate course for computer scientists is often a challenging experience, because the skills that characterize HCI are different from scientific and computational thinking that are the focus of most subjects of the curriculum. Often HCI teaching is organized as a set of lectures that are useful to learn concepts, but don't increase the design skills of the students. This work reports the results of an educational experience where both learners and teachers were actively involved in a process of knowledge construction and design. This process usually happens in other domains, such as architecture or industrial design, but is not part of most computer science curricula. We chose as project a challenging theme: the design of eco-feedback interfaces that inform people about the consequences of their actions for the environment and help to take decisions for lowering energy consumption. Eco-feedback interfaces are also representative of the gap between the products available on the market and the results of scientific studies, evidenced also by a recent workshop about HCI education. The workshop evidenced a number of pitfalls in HCI education that in our educational experience we tried to overcome with appropriate methodologies. An additional challenging task was the attempt to organize all the design activities taking advantage of a platform for remote learning, stressing its limits. The paper will discuss all these issues, evidencing where the applied methodologies gave good results and where they need further improvements, with the final goal of giving useful advices for HCI educational experiences to come.

**Keywords** Design thinking · Eco-feedback · Education · Environmental awareness · HCI teaching · Interfaces for children · Prototyping tools · Remote learning

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## 1 Introduction

HCI is an important part of the educational path of an undergraduate Computer Science student, as certified also by the curriculum guidelines that have been jointly developed and approved by the two major computer associations of computer scientists in 2013 [19]. Both theoretical knowledge and design competences are requested for complying with these guidelines. Unfortunately in most cases, as underlined also in a recent workshop [3] held at the ACM CHItaly Conference, while introductory courses in HCI are available for almost all the degrees in Computer Science, the training received is highly inappropriate. The participants in the workshop evidenced *the gap between what academia proposes and what industry actually applies* and the fact that *the integration of usability engineering methods into software development life cycles is seldom realized in industrial settings*. Most participants in the workshop agreed on the need of bridging the gap between theory and practice, providing students with technical skills they can sell in the market. The participants underlined the need of balancing design activities and HCI fundamentals, *giving more and more space to a design project* and *allocating a larger teaching effort to project reviews and sessions of co-design*. As a matter of fact, this is proposed as a remedy to the fact that most HCI courses are based on lectures. These situations are characterized by the application of cognitive-behaviourist models [9] where students are only passive listeners. The workshop evidenced also an agreement on proposing a bottom-up approach where the students design application first and understand later the applicable theory and principles. Finally the workshop's participants underlined the need to support the development of the project with tools that allow the students to make a design experience without being overwhelmed by low-implementation details.

The educational path discussed in this work, shared as a case study during the CHItaly workshop, embodies most of the challenges presented above and tries to give an answer to them with the educational solutions that will be discussed below. Besides, it focuses on an application domain, that of eco-feedback interfaces, which is currently characterized by a clear gap between the industrial products that are available and the results of scientific experimental research. Therefore the educational methodology is applied to a very relevant example of the critical situation evidenced in the workshop, with the goal of improving the design of interactive systems for the environmental awareness. In this work the analysis of existing literature played an important role for making the students aware of the importance of scientific research for designing innovative products. In particular a number of scientific works presented to the students showed the importance of using multimedia components for designing engaging interfaces, capable of attracting the users for informing them. This awareness then led to design 20 independent projects, different in style but equally committed towards rich multimedia experiences.

Another dimension of the educational design experience discussed in this work is the use of tools for remote learning. The HCI course has been part since 2013 of an educational experimentation led by our University and focused on blended learning, with a part of the course held in the classroom, and the other part with remote tools. Among the different learning models proposed for the course we chose to focus on the constructivist and connectionist models [2], targeted to the creation of knowledge and artifacts, and we managed all the educational design experience with remote tools, reserving the classroom for the lectures. As shown by the domains of architecture and industrial design [21], educational design experiences are focused on the *iterative* and *interactive* development of the project, through the supervision and the collaborative discussion with the teacher. In this experience we tried to comply with these requirements in a remote educational context, taking advantage of the features of Moodle [25], the platform chosen by our University for the experimentation.

Overall, while we don't claim that our educational experience brings definitive answers, we believe that its presentation and discussion can bring a contribution to the debate about HCI teaching methodologies and tools underlined above. In particular in this work we'll underline which educational activities worked and which didn't work, in relation to the points of weakness underlined also in the CHItaly workshop. We expect that the results of this work will be useful for the design of educational experiences to come, stimulating further the creation and experimentation of appropriate methodologies and tools for design thinking.

The rest of the work is organized as follows: Sections 2 and 3 will consider the relevant references for the domain of remote education, design experiences and eco-feedback research. Sections 4 will describe the different steps of the educational experience, including the design and the evaluation of the interfaces. Section 5 will discuss the results. Finally, Section 6 will draw the conclusions.

## 2 Remote education and design experiences

Remote learning is an opportunity that has been made possible by the availability of modern communication technology. Several tools have been designed to take advantage of it and permit a communication between teachers and learners. The size of the classes of students has progressively grown, giving birth also in the last few years to the so-called massive open online courses (MOOC) that permit a virtually unlimited participation via the web. In spite of the opportunities offered, remote learning is characterized by new challenges. For what concerns MOOCs, as evidenced in [5], there is not yet a substantial body of literature on the learning analytics; besides, experimental findings show that drop-out/non-completion rates are substantially higher than in more traditional education. Different learning models, requiring different levels of participation and active involvement of teachers and learners, have been experimented with distance education. As discussed in Anderson et al. [2], cognitive-behaviourist, social constructivist, and connectivist methods have been applied to distance education, taking advantage of different technologies. No single generation of pedagogy has provided all the answers. The authors conclude that all the cognitivist, behaviourist, constructivist, and connectivist theories play an important role in a well rounded educational experience. Cognitive-behaviourist models are characterized by a communication that is mainly oriented from the teachers to the students. Therefore one-to-many learning experiences have been created since the existence of modern mass-media, including radio and TV. Constructivist and connectivist methods require many-to-many communication, that has been available since the existence of the web. In spite of the opportunities offered by the web, scalability is an important issue, as evidenced in [2]. For this reason, the majority of web tools and experiences built with them comply with the cognitive-behaviourist method that grants a very high scalability, as shown by the success of the Coursera [6] and edX [8] MOOC platforms.

An educational design experience is usually part of the industrial design and architecture curricula [21] and requires a deep interaction between the teachers and the pupils, often organized in small working groups. The project development may start from the delivery of some foundation lectures, but then it evolves through an interactive and iterative pattern characterized by the proposal of ideas and creation of prototypes. These deliverables are constantly reviewed and modified until they reach a satisfactory and refined state that is considered as the final project. As a matter of fact, the educational design experience shares many features with the *Italian Renaissance workshop*, where the apprentices collaborated with the masters for learning their craft and eventually became masters themselves. Of course the importance of prototyping and progressive project refinement through iterative development has been longly recognized by research related to interactive systems, as demonstrated by several studies [4, 28, 32, 35]. However, as already underlined in the Introduction, the application of usability engineering methods is barely studied and seldom realized in industrial settings.

The development of an educational design experience through remote education represents an additional challenge. As evidenced above, most tools for remote education are based on the cognitive-behaviourist method that appears inappropriate for a design experience. Although a number of these tools, included the one that we used for our educational experience (i.e. Moodle), can be extended through plugins that add to them interactive, real-time features (such as interactive whiteboards for discussing the project), this solution doesn't seem to address the overall needs of the design community. As far as the knowledge of the authors of this paper is concerned, no relevant remote educational design experience takes advantage of Moodle and related plugins as foundational supporting tools. What emerges from a recent survey [23] is rather the need of a new ecosystem of tools targeted to the designers. While the survey was not specifically targeted to the educational domain, the answers by professionals acquainted with design gave precious insights about the issues related to experiences that take advantage of remote collaboration. The majority of the 275 designers that answered to the survey perceived remote design as a factor worsening the results. The survey revealed [18] that the most important negative factors that affected their remote design experience were the problems related to communication, the inability to sketch, the lack of interpersonal relationships and spontaneity. The survey identified also the categories of tools that were used by designers for facing the challenges described above: conferencing and chat tools (Skype, Google Hangouts, Slack), file sharing (Dropbox, Google Drive), online prototyping and testing tools (Invision, Marvel, UserTesting), online ethnographic tools (Revelations, Ethnio) and online whiteboards (Mural, Linolt). In short, the survey evidenced an ecosystem of interfaces, currently made by separate tools, that should be taken into serious consideration for any remote design experience, including remote educational experiences.

## 3 Eco-feedback research

We chose as theme for the educational design experience the interfaces for eco-feedback. *Eco-feedback* [10, 31] provides feedback to people about the consequences of their behaviors for the environment, with the goal of reducing energy consumption. While substantial benefits can come from the optimization of the infrastructures for the production and the delivery of energy [1], different studies [7, 10] have demonstrated the benefits of informing people about the consequences of their daily habits for the environment. Researchers have experimented eco-feedback systems for different situations, from public installations to domestic environments and personal lifestyle. For example the laser cloud in Helsinki visualizes consumption data related to urban energy consumption in the night sky [15]. For the domestic environments, where possible savings are estimated between 5 % and 15 % [27], different forms of eco-feedback are discussed in [22]. A number of mobile apps are available as well [16, 38], for calculating the personal carbon footprint and influencing the behavior of the nomadic user. The presentation format of data is a relevant issue that, as demonstrated by a number of studies, may determine the success of an eco-feedback interface. While the presentation of numeric data is often necessary for giving an accurate feedback, it fails when engaging and persuading representation is requested. As suggested by Pierce et al. [31], *pragmatic visualization* and *artistic visualization* are characterized by different perspectives, but they are both necessary for a proper communication of information. Several researchers have explored presentation modalities based on the use of abstract color patterns, such as the *Power-Aware Cord*, [12] and the *PowerSocket*, [14], and metaphorical presentations, such as the *7000 oaks and counting* project [15] that displays dynamic energy loads as a set of animated tree images. Artistic visual compositions with natural elements such as trees, clouds and flowers are proposed by Nisi et al. [29] for informing the home users about energy consumption. In spite of the general engagement offered by artistic visualization, a following study [30] underlines that this kind of visualization should be complementary to a more detailed presentation of data, confirming what evidenced in Pierce et al. [31]. Sharing consumption data with neighbors is an interesting technique that can lead to behavior changes through the introduction of competitive mechanisms. This technique was applied in Moere et al. [24], taking advantage of chalkboards positioned on the house facades for visualizing family data consumption. Different IT supported techniques, from personal interfaces for smartphones to public large screens and virtual 3D spaces, were used in the EU FP 7 IDEAS Project [33] for sharing consumption data. Of course privacy is a relevant issue that should be considered in any project related to consumption data sharing. Finally, as underlined in Spagnolli et al. [36], gaming mechanisms can be useful for increasing energy awareness and savings in the household.

## 4 Design process

### 4.1 The educational context of the study

The design proposals were developed in the context of an HCI course for the undergraduate curriculum and involved 80 students organized in 20 groups. The HCI course is part of a small group of courses of the Computer Science curriculum partecipating to the experimentation of remote education at our University. All the courses refer to the blended education model, where part of the lessons are held in the classroom and part are held using remote tools. While most blended courses are characterized by the use of the cognitive-behaviourist model, delivering pre-recorded lessons to students, the HCI course was designed for developing the whole design experience in the remote phase. According to the guidelines of our University, we had to organize the discussion and the delivery of the projects through the Moodle platform. The educational project approved for the HCI course was intentionally focused on the use of remote tools for the development of the whole design activity. Short recaps of the design activity were made at the beginning of the lessons in presence, but the classroom activity was mainly reserved for lectures. Concerning the remote tools, we activated all the channels provided by Moodle, including chats (one for week), forums and direct messaging.

### 4.2 Literature analysis and technological scouting

For the initial phase of the project we selected a set of published scientific papers related to eco-feedback and asked the students to read them. All the references are available in Appendix A.1 and A.2 of this work. This represents an uncommon choice for an undergraduate course, where usually the reference materials are books. The goal was to let the student be informed about the relevant issues of eco-feedback and let them be aware of how scientific research proceeds and how its results are made available to the scientific community. We gave to the students also a set of references to commercial products and services for monitoring the energy consumption and production. All the references were associated to short introductory descriptions. The overall goal of this phase was to let the students be aware, through the direct exam, of the gap between most of these products and the results coming from experimental scientific research. As evidenced in Section 1, this gap characterizes many situations and we wanted the students to be aware of it since the start, as a stimulus for overcoming it. We would like to emphasize that, while the transfer of research results to commercial products may be slow, as evidenced by Myers et al. [26], arriving to decades when fundamental changes of paradigm are involved, University education may play a role in shortening this time interval. In particular, this project's phase was designed for letting the students (i.e. the designers of tomorrow) acquire a work methodology based on the awareness of research results, the comparison with the current industrial products and the application of the acquired knowledge for creating innovative products.

A Moodle chat was organized two weeks after we had assigned the students the task to read carefully the papers. This chat had the goal of commenting with the students the results of the exam of these materials and extracting useful guidelines for the projects. We underline again that all the references were chosen among refereed articles published in international conferences and journals. While the discussion of the validity of the single guidelines goes out of the scope if this work, the reader can find their motivations in the single scientific articles, listed in Appendix A.1.

From this exam, the following set of useful guidelines emerged:

– provide environmental information the users can act upon;
– provide a bird's eye view of the energy consumption;
– use an engaging presentation of data as a complement to their numerical representation;
– make all the family's members mutually aware of the consumption behaviors;
– introduce gaming mechanisms for augmenting the engagement;
– use competition between neighbors for improving savings

We invited the students also to seek additional references and to include them in a wiki page that was created in Moodle for this purpose. We asked the students to include references both to scientific papers, taking advantage of the University subscription to the main computer science digital libraries, and to commercial products. Overall the students added about 20 references, listed in Appendix A.3 and A.4 of this paper. We observed that while most additional references didn't evidence further issues, this activity was useful as well for increasing the students' perception of the importance and wideness of research.

Summarizing, the overall educational goal of this phase was to inform the students, let them perceive the gap between scientific research and available commercial products and extract collaboratively useful guidelines for the project development. In this phase we started also to use different remote tools, including the chat and the forum, for supporting the students in this task. The use of these tools continued in the following phases.

### 4.3 Collaborative definition of the requirements

The analysis of literature and commercial products was preliminary to the definition of the project's requirements that were collaboratively defined with students. We started the discussion about the requirements publishing a draft on a wiki page containing a preliminary list of them, based on the guidelines evidenced in Section 4.2. The list was discussed in a long chat session in which 20 students, representatives of the working groups, took part. The discussion, as it can be seen from the final list of requirements displayed below, included very different issues. Social and economical concerns were an important part of the discussion. In particular, because economical savings can be an important motivation for the adoption of eco-feedback technologies, as underlined also in [13, 37], we encouraged students to focus on the technology available today, avoiding the proposal of very sophisticated and costly devices that would have acted as a barrier for the adoption by most families. The inital wiki page was progressively modified and, at the end of the discussion, the following list of requirements emerged:

1. Data presentation
   - electricity consumption real-time and historical data (required; detail of the single appliances optional);
   - photovoltaic production real-time and historical data;
   - water and gas consumption real-time and historical data (optional);
   - windmill production real-time and historical data (optional);
   - weather forecast, time and other contextual data (optional);
2. Visualization style
   - at least two presentation styles;
   - numerical presentation style required for adults;
3. Adaptation
   - adaptation to adults and children aged between 6 and 11;
   - adaptation to old people (optional);
4. Spatial access
   - main interface as an ambient display, shared and accessible to all the family's members;
   - ancillary interfaces deployed elsewhere (optional);
   - outdoors privacy-sensitive interface for communicating consumption and production data to neighbors;
5. Input and Output modalities
   - multimodal interface, using two or more communication channels (e.g. visual, aural, tactile);
6. Social features
   - social privacy-sensitive consumption and production data sharing;
   - social sharing based on existing or custom social networks;
7. Gaming
   - gaming mechanisms for augmenting the users' engagement (optional);
8. Cost and technical feasibility
   - technically feasible interface;
   - low cost interface, for pushing its use in a large number of families;

9. Home decor integration
   - interface as part of the home environment

We detailed also an application scenario taking into account the requirements described above: *the scenario of the eco-feedback interface is that of a family composed by two adults and two children aged between 6 and 11, living on a residential district populated by neighbors; the family lives in a house connected to the urban grid and provided with a photovoltaic plant; the interface can optionally monitor and present the consumption data of the most important appliances, including the oven, the washing machine, the dishwasher and the air conditioner; the interface can optionally monitor and present the gas and water consumption data and the production data deriving from a windmill.*

Summarizing, the overall educational goal of this phase was to give the students the opportunity to collaborate to the definition of the requirements and to fully understand their meaning through the discussion, for a conscious application to their projects.

### 4.4 First design proposals

Following the tradition of industrial design and architecture, we asked the students to deliver a first draft of their ideas using visual sketches, compliant with the requirements and the application scenario discussed above. Sketches are a powerful tool for reasoning and detailing a project, but are not a primary activity for undergraduate Computer Science students. Unfortunately they are perceived by a number of students as an activity requiring specific artistic skills. Therefore we insisted in this phase to consider sketches as a tool for the design work. We provided as a reference the book *Sketching User Experiences: the Workbook* by S. Greenberg et al. [11], which features many useful examples that show how sketching can be profitably used by anyone for expressing an interaction design concept. To emphasize the fact that sketching is not a naive activity, we required the groups to accompany their sketches with a written document, detailing the relation of their visual proposals with the scientific papers provided to them and the mappings with the requirements and the scenario described above. A chat session was organized for supporting this task before the final projects' upload. We discussed with the students several issues, among which the importance of having a rational and well-established starting point and basing the design work on relevant experimental research. A number of requirements needed further clarification. In particular we discussed the role of the eco-feedback devices as social artifacts that had to be available to all the family's members for mutual awareness and stimulating discussion. For this reason we explicitly discouraged projects based mainly on personal devices. Besides, we clarified the concept of adaptability, which was considered inappropriately by some students as the possibility to define separate devices for different classes of users, instead of single artifacts capable of adapting the interaction with users.

Figure 1 displays the first draft proposed by one of the working groups, showing the main artifact for monitoring electricity and water data. The color of the tree on the left, made of optical fibers, varies according to the balance between the production and the consumption of electricity. The color of the circles on the right changes for showing how the current water consumption compares to the mean of the previous days. The project includes the proposal of a bracelet for informing the family's members about consumption and production even when they are not in the main room and, in the case of anomalies, attracting them towards the main interface.

Summarizing, the overall educational goal of this phase was to let the students begin to experiment sketching as a method to express a design idea and to focus on the necessary

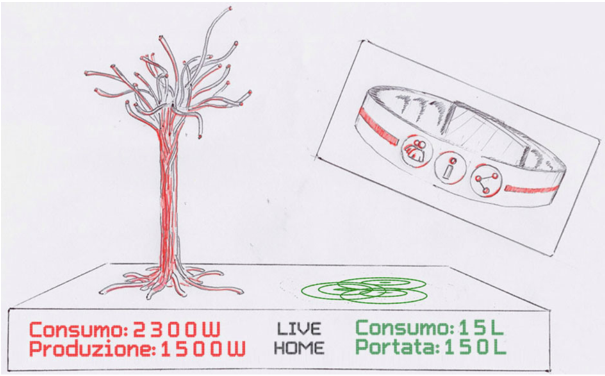


**Fig. 1** One of the sketches related to the first project proposal, showing the main interface for the family and a sample of a complementary bracelet for the family's members. The base of the main artifact displays electricity production and consumption data (*on the left*) and water consumption data (*on the right*)

relation with the requirements, for avoiding the elaboration of naive solutions based only on ideas not well founded.

## 4.5 Review and peer-review of the first design proposals

We managed the collection of the first design proposals through the Moodle *workshop* tool. Its use permitted the students to receive detailed feedback from the teacher and to experiment also the peer review among colleagues belonging to different groups. We would like to underline that while peer review is ordinarily and profitably used among experts in scientific research, its rough application with newbies can originate a sense of lack of guidance. For this reason, while we wanted the students to experiment the importance of receiving comments from peers that played the part of potential users of the interface, we complemented this review with the ordinary teacher's review. At the end, each group received a detailed list of comments by the teacher and four additional reviews deriving from the peers' involvement (each student was assigned the review of one project belonging to another group). The projects' reviews revealed that half of the 20 projects were satisfactorily organized and contained interesting ideas properly mapped to the design requirements. Only a small number of groups were asked to perform major revisions, mainly for achieving a coherence with the design requirements. Summarizing, the overall educational goal of this phase was to let the students know the importance of receiving feedback from various sources during the projects' composition and to experiment the peers' review as a way to expand the feedback. In this phase we started to introduce the students to the incremental iterative project development that continued in the following stages.

## 4.6 Final design proposals

The projects were developed using an iterative incremental approach, suggested, as stated before, by current practice in architecture and industrial design and usability engineering techniques. We learned from the HCI educational experience of the previous academic years that involving students in low-implementation details requires a lot of effort and, most importantly, distracts them from maintaining the focus on the design of interaction that should be the core of their work in this course. This finding was coherent with the observations emerged from the CHItaly workshop (see Section 1). Therefore we asked the students to elaborate their revised proposals using two prototyping techniques well-described in Greenberg et al. [11]: the *narrative storyboard* and the *branching storyboard*. Both techniques don't require the students to be involved in low-implementation details. The narrative storyboard permits to describe relevant intervals of the user experience using sequences of sketches. Several aspects of the interaction can be described thanks to the use of this technique: the interface of the device, the user direct and indirect action, the context in which the interaction happens. Some samples of the narrative storyboards realized by the students are presented in Fig. 2. The sequences were realized taking advantage of different techniques, including drawings, photographic snapshots and 3D models. All the content was composed using simple image manipulation tools, such as Gimp. We supported the groups that wanted

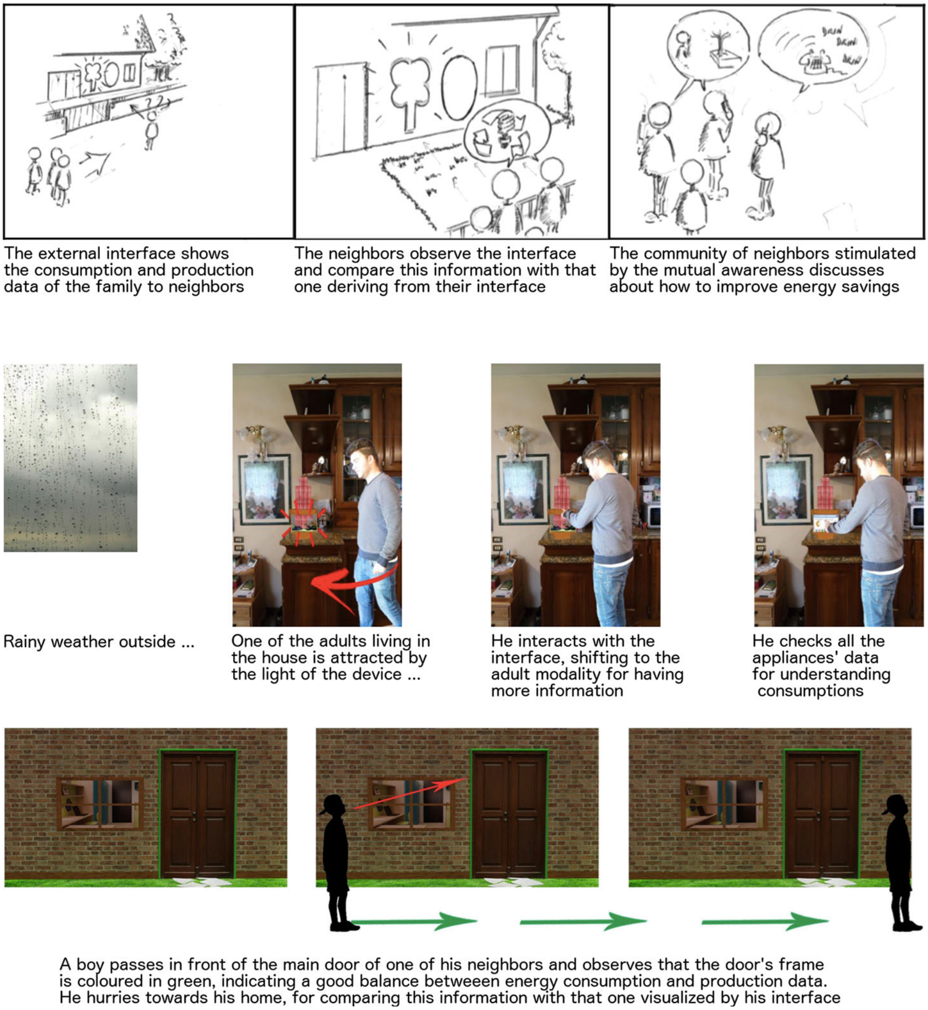


**Fig. 2** Three examples of narrative storyboards

to give a more realistic representation of their projects with a set of tutorials focused on SketchUp [34], a free 3D modeling tool characterized by a low learning curve. The tutorials complemented the official tool documentation and gave the students useful hints and examples related to the specific theme of the project.

The branching storyboard is a more elaborate prototyping tool that permits to visualize the different states of the interaction and to describe the events (i.e. the user action, the flow of production and consumption data) that trigger state's changes. For the composition of the branching storyboards we asked the students to take advantage of Invision [17], a web application that can be used to manage sets of screens containing wireframes or other types of representation. The application allows to connect them through hypermedia links, activated by hotspots defined by the authors on the top of the screens themselves. We chose

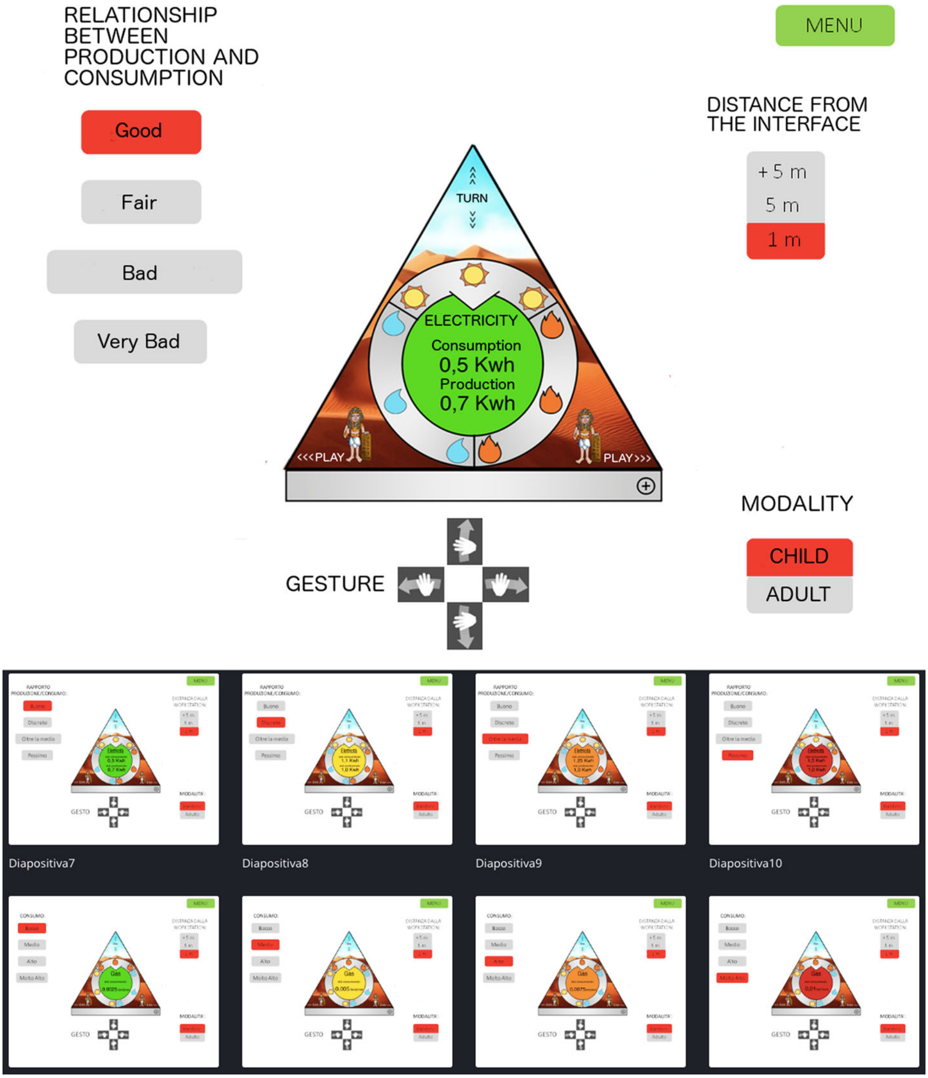


**Fig. 3** An example of branching storyboard

this tool because is characterized by a very low learning curve and permits a flexibility for delivering the results (i.e. publishing them on the web or uploading them for off-line viewing). Figure 3 reports an example of branching storyboard realized with the Invision tool. The lower part of the figure displays a set of screens corresponding to the different states of the interface. The upper part of the figure represents the screen of the storyboard currently visualized by the user. The multimedia pyramid, the main artifact of the represented project, is displayed in the center of the screen. It is surrounded, in the interactive representation, by sets of buttons that permit to simulate changes of state deriving from the user direct and indirect actions and data modifications. For example, in Fig. 3, the red buttons (i.e. the color evidences the *selected* state) show that the representation of the pyramid is related to a favorable balance between energy production and consumption (button with label *good*), to a short distance of the user from the pyramid (button with label *1 m.*) and to the fact that the user has been recognized by the system as a child (button with label *child*). Besides, the set of buttons displayed under the pyramid permits to simulate the activation of different gestures (i.e., for this project the students proposed to include in their device a low cost 3D depth camera for detecting hand gestures, which were mapped to different functionalities).

As a complement to the prototyping activity, we asked the groups to compose a short video, with the goal of describing the project proposal to one of the classes of potential users defined in the initial requirements: the children aged between 6 and 11. We suggested, as the bottom-line for the video preparation, to record a sequence of self-paced Powerpoint slides with an audio track as a mp4 video file, with a maximum length of 3 minutes. The working groups were however left free to use any composition tool they were comfortable with. A selection of video screenshots taken from two projects is available in Fig. 4.

Even during this phase we used the Moodle chat for discussing with the students the issues related to the project. In particular we discussed how to use the prototyping techniques, which represented a novelty for the students, and the features of the video that were asked to compose. We used the Moodle workshop tool as well, for managing the upload of the projects. All the groups were requested to upload the storyboards accompanied by a complementary set of descriptive textual documents.

Summarizing, the overall educational goal of this phase was to let the students experiment visual prototyping techniques and tools without being involved in low level issues. Besides, at the beginning of this phase we introduced the request of preparing a video for the children for stimulating further the students' attention towards this class of users and making them aware of the importance of having a feedback from all the categories of users.


**Fig. 4** A selection of video screenshots illustrating two different projects' proposals

### 4.7 A summary of the final design proposals

The working groups delivered 20 final independent project proposals. The vast majority of them were compliant with the compulsory requirements and the scenario described in Section 4.3. Design practice shows that starting from the same constrains (i.e. requirements) may lead to very different solutions. The 20 projects were no exception in this respect. The goal of this section is to give the readers insights about how the degrees of freedom given to students (including the application of the optional requirements) were interpreted for the design proposals.

Table 1 offers a synthetic view of the dimensions analyzed, in reference to the requirements described in Section 4.3. For the clarity of reading, we didn't list the compulsory requirements that were satisfied by all the working groups, but rather we focused on how they were interpreted or how the students explored the design space of the optional requirements.

**1 - Data presentation** The indoor devices were usually characterized by a rich interface, offering a lot of information about energy. All of them offered comparisons related to the balance between consumption and production and details about the consumption of the different appliances. Often the working groups presented also the data related to additional consumption and production sources (9 out of 20, see Table 1-1). In many cases (15 out of 20) the interfaces offered additional information that went beyond eco-feedback data, such as the time of the day or information about the weather, with the goal of attracting the family members towards the devices and making them to see also the eco-feedback information. Even for the outdoors artifacts a number of groups tried to attract the attention by adding complementary information, such as the weather forecast or the time of the day, or augmenting existing objects targeted to other functions, such as the doorbell. Overall the students evidenced in their projects the need of giving a complete information and attracting users towards environmental data with other useful data.

**2 - Visualization style** All the projects used the numerical data representation. However, in compliance with the initial requirements, other presentation styles were used as well. These presentation styles often preceded the numerical representation, for providing an initial interface comprehensible also to children. All the groups chose to use the abstract representation as complementary presentation modality, using colors, patterns and shapes. A relevant number of groups (13 out of 20, see Table 1-2) proposed the metaphorical presentation style. Many groups took advantage of all these presentation modalities, using them in different situations and for different classes of users (i.e. the metaphorical representations were mainly used for the children's interface).

**3 - Adaptation** Most groups interpreted in a satisfactory manner the adaptation requirement for improving the comprehension of adults and children (i.e. only 1 group out of 20 failed in this respect). We noticed a strong tendency to create *adaptable* interfaces (15 out of 20, see Tables 1-3), that is interfaces that required the explicit user intervention for changing the adult/child modality (see Fig. 5a). Most interfaces defaulted to the children presentation modality, offering different mechanisms for changing it. For a limited number of projects (3 out of 20) the students proposed the *adaptive* approach. In this case implicit interaction mechanisms provided an automatic switch to the adult modality. Some of these mechanisms were based on the measurement of the users' height for deriving their age (see Fig. 5b), while others required the users to wear a sensor that identified them as adults while they

**Table 1** Summary of the 20 final conceptual projects (*x* stands for the availability of the feature, . for its lack)

| Parameter | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1- Data presentat. | | | | | | | | | | | | | | | | | | | | | |
| addit. sources | x | . | x | x | . | x | . | . | . | . | . | . | x | x | . | . | x | x | x | . | 09 |
| additional infos | x | x | . | x | x | x | x | x | x | x | x | x | . | . | x | x | x | . | x | . | 15 |
| 2 - Visual. style | | | | | | | | | | | | | | | | | | | | | |
| numerical style | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 20 |
| abstract style | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 20 |
| metaph. style | x | x | x | x | . | x | x | x | x | x | . | . | x | . | x | . | x | x | . | . | 13 |
| 3 - Adaptation | | | | | | | | | | | | | | | | | | | | | |
| adaptable | x | x | . | x | x | x | x | x | x | x | x | . | . | x | . | x | x | . | x | x | 15 |
| adaptive | . | . | . | . | . | . | . | . | . | . | . | . | x | . | x | . | . | x | . | . | 03 |
| 4 - Spatial Access | | | | | | | | | | | | | | | | | | | | | |
| add. indoor dev. | . | x | . | . | . | . | . | . | . | . | . | x | x | . | x | . | . | x | . | . | 05 |
| wearables | . | . | . | . | . | . | . | . | . | . | . | . | x | . | . | . | . | . | . | . | 01 |
| 5 - I/O Modalities | | | | | | | | | | | | | | | | | | | | | |
| visual output | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 20 |
| tangible output | . | x | . | . | . | . | x | . | . | . | . | . | . | . | . | . | . | . | . | . | 02 |
| audio output | x | . | . | . | . | x | . | . | . | x | x | x | . | x | x | . | x | . | . | x | 09 |
| physical input | x | . | . | . | . | . | . | . | x | . | . | . | x | . | . | . | . | . | . | . | 03 |
| touch input | . | x | x | x | x | x | x | x | . | x | x | x | . | x | x | x | x | x | x | x | 17 |
| gestural input | . | . | . | . | . | . | . | . | . | . | . | . | . | . | x | . | . | . | x | . | 02 |
| audio input | . | . | . | . | . | . | . | . | . | . | . | . | . | . | x | . | . | . | . | . | 01 |
| tangible input | . | . | x | . | . | . | . | . | . | . | x | . | . | x | . | . | . | . | . | . | 03 |
| impl. interact. | . | x | x | . | . | . | . | . | . | . | x | x | x | x | x | . | . | x | x | . | 09 |
| 6 - Social Features | | | | | | | | | | | | | | | | | | | | | |
| Facebook et al. | x | . | . | x | x | . | x | . | x | x | x | . | . | x | . | . | . | . | x | x | 10 |
| custom social n. | . | x | x | . | . | x | . | x | . | . | . | x | x | . | x | x | x | x | . | . | 10 |
| 7 - Gaming | | | | | | | | | | | | | | | | | | | | | |
| gaming mech. | . | . | . | . | . | . | . | . | x | x | x | . | . | . | . | . | x | . | x | x | 06 |
| 8 - Cost/Feasib. | | | | | | | | | | | | | | | | | | | | | |
| low-cost | x | x | x | x | x | x | . | x | . | x | x | . | . | x | x | x | x | . | . | x | 14 |
| middle-cost | . | . | . | . | . | . | x | . | x | . | . | x | x | . | . | . | . | x | x | . | 06 |
| 9 - Home Decor | | | | | | | | | | | | | | | | | | | | | |
| indoors integr. | x | x | . | . | . | . | x | . | x | x | . | x | x | . | x | x | x | x | x | . | 12 |
| outdoors integr. | . | x | . | x | . | x | x | . | x | x | x | x | x | . | x | x | x | x | x | x | 15 |

The final column (T) summarizes the number of occurences for each feature

were getting near to the main eco-feedback interface. In the case of a prolonged inactivity, most systems automatically returned to the children oriented visualization.

**4 - Spatial accessibility** All the solutions complied with the requirement of positioning the interface in a room accessible to all the family members. In some cases (5 out of 20, see

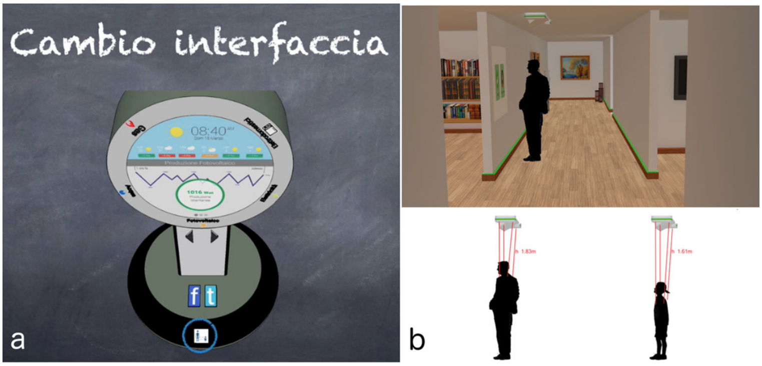


**Fig. 5** Explicit vs. implicit interaction: **a** a button on the base of the artifact allows to shift between the adult/child visualization modalities **b** the artifact measures the user's height for determining her age and presenting automatically proper information

Table 1-4) the groups added secondary devices for giving the users contextual information related to the different rooms of the house. One of the groups interpreted the possibility to introduce additional devices proposing wearable artifacts (see the bracelet in Fig. 1).

**5 - Output and input modality** For the output, the visual channel was exploited by all the proposals (see Table 1-5). In some cases the presentation was integrated by audio signals that had both the goals of informing and attracting the family members passing near the devices. The possibility of presenting data through tangibles was explored by two groups. The most unconventional presentation involved the use of fluids contained into a set of glass cylinders (see Fig. 6a) for presenting the energy data. Overall 11 groups out of 20 took advantage of multimodal output modalities.

The most adopted input modality was characterized by the use of touch (17 out of 20, see Table 1-5), most probably a consequence of the wide diffusion of smartphone and tablet devices. Less adopted input modalities included the use of physical buttons (3 projects, see for example Fig. 5a), gesture-based input for communicating with the main eco-feedback artifact (2 projects, see for example Fig. 3), tangible input (2 projects, see for example Fig. 6b) and vocal input (1 project). Only 6 groups out of 20 took advantage of multi-modal input modalities. The working groups considered interesting, for a relevant number of projects (9 out of 20, see Table 1-5), the input derived from implicit interactions. Implicit interactions, according to Wu [20], are interactions that *occur without the explicit behest or*

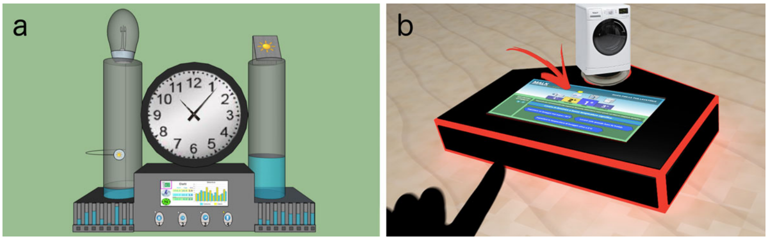


**Fig. 6** Tangible interfaces: **a** an artifact presenting energy data using fluid levels **b** visualization of consumption data triggered by the manipulation of 3D-models of domestic appliances

*awareness of the user. Such interactions are employed when the user is focused on something other than trying to get an interactive device to do what they want*. This type of interaction, as underlined to students in one of the course lectures, is typical of situations where the interactive device and its functionalities mingle with the objects and the activities of everyday life, as it may happen in the home environment that was the scenario for their project. In the students' works implicit interaction was associated to the beginning or to the end of the interactive session and took advantage of sensors embedded in the environment or worn by the users for monitoring different parameters, such as their position in relation to the main eco-feedback device.

**6 - Social features** All the groups complied with the requirement of sharing consumption data with selected members of social networks. While for half of the cases the design proposals relied on widely known social networks such as Facebook, the other projects expressed a preference for sharing data with ad-hoc social networks (see Table 1-6).

**7 - Gaming mechanisms** The introduction of gaming mechanisms was an optional requirement considered by a minor yet relevant percentage of working groups (6 out of 20, see Table 1-7). All the proposals were focused on the children interface. Some groups took advantage of cartoons' characters for engaging the children, giving them useful advice about the environmental behaviors or testing their skills with a set of questions (see Fig. 7a and b). Another project gave the children the possibility to play with gadgets (representing characters or physical objects of common use) for having information about the consumption of the different appliances (see Fig. 6b). For all the projects the goal was to increase the interest of the young category of users.


**Fig. 7** Two examples of games: **a** children gain badges by putting in the proper order the components of a consumption chain that takes advantage of renewable sources **b** children fight against the evil snake and save the good fish if they follow its positive advices, such as turning off unused lights or switching off TV

**8 - Cost and technical feasibility** All the projects proposed feasible solutions, taking advantage of existing technology. Besides, all the projects kept in mind the constraint of avoiding very costly technologies. However it is possible to distinguish (see Table 1-8) low-cost (<300 euro, as most available eco-feedback devices) and middle-cost projects (<600 euro). In the latter case the major cost was usually due to the introduction of ancillary devices, such as secondary displays or wearables.

**9 - Home decor integration** The majority of the projects (12 out of 20 for indoors and 15 out of 20 for outdoors, see Table 1-9) showed an attention for integrating the proposals with the home decor. For indoors, the artifact took often the shape of lamps, paintings or decorative objects (see Fig. 8) or were integrated as part of existing objects, such as the frames of light switches. Even for outdoors the devices took the shape of objects that usually characterize this environment, such as doors, lamps, fountains and other artifacts (see Fig. 9). In most cases the authors related the color of the artifacts or of some parts of it to the energy consumption, to the balance between energy consumption and production or to improvements in the family's habits. The fountain represented in Fig. 9 had similar purposes, representing the mean consumption with the dynamic level of the liquid contained in the cylinder.

Overall the projects demonstrated a great variety of solutions, respecting for the vast majority of cases the constraints fixed at the beginning of the development.

### 4.8 Final evaluation

The first evaluation, described in Section 4.5, was realized by an expert evaluator (i.e., the teacher) and his judgment was complemented by the opinions of the peers. In both cases the opinions were expressed by persons that may be considered also as representatives of one of the classes of users for which the interfaces were created: the adults. The second evaluation included again the teacher's intervention, but was complemented by the opinions of a group of children, representatives of the second class of users described in the application's scenario. Besides, the projects received also an external evaluation by a colleague, expert in HCI, of the University of Toulouse. The evaluation, rather than being based on quantitative metrics, was mainly qualitative, based on the long HCI expertise of the colleague and addressed to select the works more promising for future development, in relation to current trends in HCI research.

As far as the children were concerned, we involved a class of the Primary School, composed by 19 children aged 10 that had already a general knowledge of the themes related


**Fig. 8** Three different proposals for the indoors interfaces: **a** lamp **b** tree made of optical fibers and bracelet **c** decorative artifacts

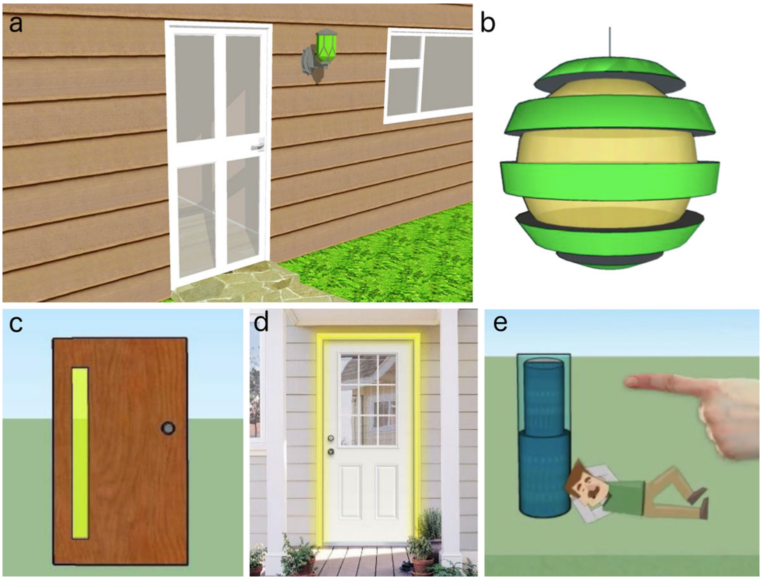


**Fig. 9** A gallery of outdoors interfaces: **a** lantern **b** lamp **c–d** doors **e** fountain

to environmental awareness. As a matter of fact, in the region where the study was held, the educational programs of the Primary School include basic notions of environmental awareness, with a specific focus on waste recycling and energy savings. The children evaluation was based on the observation of the 20 short videos prepared by the undergraduate students (see Section 4.6). Figure 4 displays two video sequences taken from the presentation of different projects, realized by the students. Of course an evaluation based on the exam of the interactive storyboards would have resulted in a more accurate feedback, but for organizational constraints it was not possible to organize it with the children.

We dedicated a full morning (about 5 hours overall) for playing all the videos in the classroom (see Fig. 10), with frequent pauses that were necessary for avoiding diminished levels of attention. The videos followed a brief presentation focused on the themes of energy savings and on the interfaces that may help to obtain these savings. After each video the children were asked to fill in a paper questionnaire, related to the project that had been just presented, organized as follows:

- 5 closed questions based on a 5-points scale focused on: the perceived usefulness of the interface, its perceived ease of use, its aesthetic quality, the willingness to have the device at home and the clarity of explanation of the interface features;
- 2 open questions focused on the most appreciated features and the worst defects of the interface;
- 1 final mark based on a 10-points scale, compliant with the school marks of the Italian educational system

As it can be seen in Table 3, the 5 closed questions were formulated using verbal expressions that could have been easily understood by 10 years old children and that were checked by the teachers before the evaluation. Besides, before the beginning of the evaluation we read all the questions in the classroom, asking the children if they had fully understood them.

**Fig. 10** At the Primary School for evaluating the eco-feedback interfaces

Please note that, given that the students evaluated a set of conceptual projects on the basis of a set of videos, we tried to evaluate the *perceived* usefulness and ease of use of the interface. This evaluation of course has a lower value compared to an evaluation with a real prototype; in spite of these limits, we introduced it as part of the educational experience, with the goal of giving the undergraduate students of the University a feeling of the variety of opinions of the potential classes of users.

The goal of the external review by the colleague of the University of Toulouse was to highlight the most promising projects in relation to the most interesting trends in HCI. The result of this evaluation was returned as a ranking of the projects accompanied by a summary of the motivations.

The results of these evaluations were returned to students at the end of the experience, that included also a final event at at the Scientific Campus of our University where we honored the best projects according to the expert and the children rankings, with a contextual explanation of the motivations.

## 5 Discussion

The results of this experience were interesting for many complementary facets that will be evidenced in the following discussion.

### 5.1 HCI educational results

The goal of this project was to design a successful HCI educational experience. As discussed in a recent ACM workshop [3], HCI education suffers from a number of issues that should be overcome for giving proper knowledge and skills to computer science students. The educational experience described in this work tried to focus on all the issues evidenced in the workshop discussion. Table 2 resumes the guidelines that may be derived from the ACM workshop and the activities, described in the previous sections, that in our experience represented a possible implementation of them.

We don't claim that our educational experience gives a definite answer to all the issues underlined in the workshop, nor we offer a comparison with alternate experiences based on different methodologies. However we underline that our proposals are compliant with

**Table 2** Summary of the guidelines emerged from the CHItaly workshop and the activities of the design experience

| Guideline | Activities |
|---|---|
| 1 - Realize a good balance between theoretical and design activities; for most HCI courses the focus is only on the first type of activity | The course activities were equally split among lectures and design activities; the latter activities were realized through remote educational tools |
| 2 - Give room to an iterative and interactive development of the project, based on reviews and co-design | The project development included phases of design and review that were iterated to shape a refined project proposal; during the design phase the students were supported with chat sessions; the projects received different types of review and feedback, which were given by the teacher, the external reviewer, the peers and the children; the students were actively involved in all the phases of the project, including the collaborative definition of the requirements |
| 3 - Fill in the gap between scientific research and industrial practice | The project started from the exam of the available scientific literature and the commercial products, with the two-fold goal of letting the students perceive the gap and identify the most interesting research findings, which became requirements for the design proposals |
| 4 - Support a bottom-up approach where the students design the application and understand later the theory and the principles | The students learned the importance of different HCI methodologies with the direct experimentation (e.g. collaborative development, peer evaluation, user feedback); the theory lessons in the classroom focused on theories and principles (e.g. adaptive interface, ubiquitous computing, usability heuristics) that were seen in relation to the issues emerging from the project development |
| 5 - Manage the design experience without involving students in low implementation detail | The students used sketching techniques and visual tools for developing conceptual projects, maintaining the focus on design rather than on implementation |

the constructivist and connectivist educational models [2], which are proved to be useful for situations (like our educational experience) focused on the creation of knowledge and artifacts. Besides, we collected from the experience a number of qualitative indicators that can help to analyze the results of the design experience and to understand what it worked.

We analyzed the educational results of this design experience along three different dimensions: the quality of the final conceptual projects, the students' participation in the different activities, the students' opinions about a number of dimensions of the design experience.

As far as the quality of the projects is concerned, more details will be given in Section 5.2. However we would like to mention here that most projects were actually addressed to fill in the gap between the experimental research and the existing commercial products, taking into proper account the design requirements fixed in the first phase of the experience. A number of these projects were considered interesting for further development by an independent review, held with the collaboration of an expert researcher of the University of Toulouse. We can infer that, from an educational point of view, the introduction of the exam of the relevant literature, the collaborative extraction of the guidelines and the discussion of the requirements worked and can be considered as a possible implementation for the third guideline of Table 2. Following the results, we suggest to use these techniques for further educational HCI design experiences.

Another positive indicator of the experience is that students participated actively in the different phases of the project, as demonstrated also by the logs of the Moodle platform. All the groups completed their projects by the first session of the academic year, demonstrating also in this respect an interest for the course's activities. The online chat was one of the tools preferred by the students for interacting with the teacher. The students appreciated the use of many to many communication and social communication, confirming the appropriateness of the association of these tools to methods that lead to knowledge and artifact creation [2]. Our suggestion in this respect is to improve further the use of this kind of communication, evidenced as part of the solutions for the second guideline of Table 2, in further HCI design experiences.

After the end of the course we asked the students to give an overall evaluation of the design experience, asking also their opinions about the modalities of the reviews and about the fact that their work might have been a starting point for future development by the students of the University of Toulouse. Table 3 resumes the results in relation to a 5-points scale. The overall design experience received a positive score (3.85 out of 5). The evaluation of the projects by external reviewers was considered important by the students, with a particular reference to the evaluation performed by the children (4.04). Even the possibility, discussed in the classroom, that the projects might have been considered for further development was held in high regards by the students (4.42). We can infer from these answers that the students understood the value of direct experimentation, collaborative development and review addressed by the second and fourth guideline of Table 2. Therefore we recommend the use of this approach for further educational experiences.

**Table 3** Final questionnaire, based on a 5-points scale, for collecting the opinions of the students about the educational experience

| Question | Mean |
|---|---|
| How do you evaluate the overall design experience? | 3.85 |
| How do you evaluate the involvement of external reviewers for the project's evaluation? | 3.08 |
| How do you evaluate the fact that the best projects might carried out by the students of another University? | 4.42 |
| How do you evaluate the involvement of the children for the project's evaluation? | 4.04 |
| How do you evaluate the overall project workload? | 3.27 |

The score assigned to the workload (3.27) confirms that the design activity was perceived as something different from the other activities of a computer science undergraduate curriculum. The result related to the workload is coherent with the value registered in the official questionnaire that each student has to fill in at the end of any course; the questionnaire is anonymous and contributes to the evaluation of the teaching quality at our University. The score is slightly lower than the means of the other Computer Science courses, but it is largely improved if compared to the scores registered for the past editions of the course, where the students had been requested to realize full implementations of their prototypes. This result, complemented with the quality of the projects, suggests the usefulness of a methodology based on sketching techniques and visual tools that don't require the students to be involved in low-level implementation details. This methodology represents therefore a possible implementation of the fifth guideline described in Table 2 and we recommend to use it for HCI design courses. At the same time the comparison of the perceived workload with the other courses seems to suggest that design thinking is still perceived as something different (and more demanding) from the scientific and computational thinking required for most of the other courses. The teaching method that characterized this course required a high level of interactivity and was perceived by some students as highly demanding, because students were often invited to express their opinions and to comply with deadlines. Both these issues are worth of further reasoning and refinement for the next editions of the course.

### 5.2 Remote learning and design

We split equally the time of the educational experience between lectures and design activities, in compliance with the first guideline of Table 2. The use of remote tools for the management of the whole design activity represented an important variable of the experience, and of course was not the only possible implementation of the guideline. The HCI course was part of a group of courses of the Computer Science curriculum that participated in the experimentation of remote education. All the courses participating in the experimentation referred to the blended education model, where part of the lessons were held in the classroom and part were held using remote tools. However, while most blended courses were characterized by the use of the cognitive-behaviourist model, delivering pre-recorded lessons to students, we experimented the management of the projects in the remote phase, trying to understand the potential and the pitfalls of this kind of experiences.

In our experience, Moodle, the tool chosen by our University for experimenting remote and blended education, demonstrated to be a useful platform for delivering materials, for managing the distribution of documents (including the managing of the peer review) and for some collaborative activities (such as wikis and chats). However in a number of circumstances we felt the need of a richer and more interactive platform. For example the use of the chat for discussing the project was very appreciated by the students, who preferred it to less interactive tools like the forums, but lacked some very basic features, such as the possibility to share documents and web links or to perceive the presence and the ongoing actions of the remote users. In our experience, the design activities were created with external tools, such as Invision, that filled in the gap with functionalities that were not available for the Moodle platform.

While some limits of Moodle can be overcome thanks to the addition of useful plugins, such as collaborative whiteboards, we are not aware of any significant educational design experience built on the top of this platform. As a matter of fact, what would be needed is a novel ecosystem of cooperating tools focused on design activities. While such educational platform doesn't exist, some interesting suggestions emerge from the survey about remote design [23] in which the designers were asked about which tools they used for remote design. Although the focus of the survey was more on design practice rather than education, it represents an interesting starting point, both because of the high number of designers that answered (i.e. 275) and because of the fact that an educational design experience has many points in common with a professional experience, as it results from the analysis of the industrial design and architecture domains. Some of these tools already offer some integration possibilities (e.g., a novel version of the Invision tool permits to share projects and comments with a live whiteboard and to access resources using a shareable Dropbox repository) and hopefully this trend will continue. Therefore our suggestion for a full implementation of the second guideline of Table 2 in a remote educational context is to take advantage of tools that support design activities and that allow integration and online sharing. The educational path described in these pages represents a transition towards this kind of experiences that we'll support better in the following editions of the course, for granting a smoother and more interactive design experience.

### 5.3 Eco-feedback projects

The path described in this work is primarily an HCI educational design experience that led to the design of conceptual projects. Therefore a full evaluation of the projects was not possible and however was out of the scope of this work. In spite of that, in this section we'll discuss the results emerging from the reviews of the projects, with a particular reference to the external review made with the collaboration of the University of Toulouse and the feedback given by the children. As evidenced in Section 4.8 the external evaluation was made by an expert HCI researcher and its goal was to highlight the most interesting projects. The result of this evaluation was returned as a ranking of the projects accompanied by a summary of the motivations. *Netenergy* (Fig. 1), *Lighty* (Fig. 4-row 1) and *T-Planet* (Fig. 4-row 2) were considered as the most interesting attempts to fill in the gap with the existing commercial products and to propose a design solution compliant with the guidelines suggested by scientific research. *Netenergy* is a project that proposes as a main artifact a tree made of optical fibers that presents information about energy production and consumption through color codes. The base of the artifact presents also information about water consumption with a set of colored circles. Numerical information is added when the user gets near to the artifact. The authors of this project introduced wearable artifacts (bracelets) for controlling the state of the system and notifying anomalies. The authors proposed also a simplified bracelet for children, which triggers the access to a presentation format of data more suitable to young users. Bracelets have also a social purpose, stimulating the discussion about environmental themes with people met outside the home environment (e.g., while walking at the park). The project was considered interesting for its smooth integration with the home environment and activities and the possibility to represent different types of energy. Even the metaphorical representation of the tree was considered appropriate with the idea of sustainability. *Lighty* features, as the main artifact, a lamp showing data about energy production and consumption through colored bands of varying length. The numerical visualization is reserved to small terminals placed on the walls of the rooms, which present contextual information related to each specific space as well. The authors of this project proposed also to take advantage of Powerline technologies for monitoring the consumption of the different appliances. Finally the project features a nice artifact (see Fig. 4, third frame of row 1), to be placed on the outdoor walls, which attracts the attention of the neighbors, offering complementary information related to the weather and to the time of the day. *In short, Lighty* was considered very interesting for its integration with the interior decor, the contextual display of room-related information, the elegant artifact for outdoors and the possibility to monitor the consumption through the existing electric wire avoiding wireless transmission. *T-Planet* presents information related to energy production and consumption through colored bands integrated with the home skirting and the doors' frames. This mechanism is adopted both for indoors and outdoors. Detailed information is offered by a small projector that is activated by the user passing nearby. A low-cost sensor is used for determining the user's age through the height's measurement (Fig. 5b) and presenting information with the appropriate format. This project was considered worth of consideration for the use of light patterns integrated in ordinary components of the house, the implicit interaction mechanism, the simple interface appearing as one of the pictures hung to the house's walls.

Also the evaluation with children gave positive results. The answers to the initial 5 closed questions, summarized in Table 4, revealed positive values with low standard deviations about the perceived usefulness, ease of use and aesthetic value, with a slightly higher polarization about the willingness of the children to have the devices in their homes. The mean for the final mark, measured along the 10-points scale, was 8.73, with a standard deviation equal to 0.54. Again we want to remark that the children expressed their opinion in relation to interfaces that were described in a clear way (mean 4.08) but that they couldn't operate with. Analyzing the single projects, we noticed a tendency by the children to assign higher scores to artifacts that mingled with the other objects of the home environment or took advantage of gaming mechanisms to promote positive environmental behaviors. For what concerns the open questions, focused on the most appreciated features and worst defects, the children declared a preference for the interfaces with a good aesthetic quality, the presence of animated characters and gaming mechanisms (e.g., see the prototypes presented in Fig. 7). Of course the prolonged interest for these features should be evaluated with a long experimental study that was out of the scope of this work. Among the negative features, the children in some cases underlined that energy was measured with units they could not understand (e.g., KWh.), confirming what is described in [13] in relation to the meaningfulness of certain representations. Besides, the children underlined the difficulty to understand the meaning of certain abstract or metaphorical visualizations.

**Table 4** The mean scores related to the children's answers to the 5 closed questions, derived from the exam of the videos

| Parameter | Mean | St. dev. |
|---|---|---|
| How much understandable was the explanation of the operation of this interface? | 4.08 | 0.31 |
| Do you think that this interface can be useful for suggesting positive behaviors for the environment? | 4.06 | 0.20 |
| How easy to use seems this interface? | 3.91 | 0.33 |
| How beautiful is this interface? | 4.02 | 0.28 |
| How much would you like to have this interface at home? | 3.78 | 0.40 |

The answers are related to a 5 points scale

We underline that a number of features that were considered by the children as worth of interest (e.g., the gaming features) differed from those one underlined by the teacher and by the external evaluation. As already stated, from a pedagogical point of view, this made evident to the undergraduate students the importance of extending the evaluation to all the categories of users, in order to receive complementary feedback for the following development.

## 6 Conclusion

The work presented in these pages described the development of an educational design experience. We described in this paper the solutions that we adopted and the results that we obtained, in relation to the points of weakness evidenced also in a recent ACM workshop, with the goal of contributing to the discussion about how HCI education can be improved. We tried with our work to rebalance the relation between theory and design; the latter should be an important part of an educational experience, especially for the students that will have a design role in the industry. Scientific and computational thinking play a major role in the current Computer Science educational curricula, but should be complemented by the possibility to have educational experiences focused on design thinking. The bet is that these experiences should serve to diminish the gap between research and industry which for certain application domains, such as that one of eco-feedback interfaces, is particularly relevant. The scalability of this type of experiences, based on constructivist and connectivist methods [2], is another important factor as well. The organization of a design course requires much more involvement from the teacher for coordinating many activities, reviewing frequently the design proposals and coming to satisfactory results. The activity is heavily dependent from the number of students as well. The use of remote tools played an important role in this experience. The results obtained and the analysis of the survey about the use of appropriate tools for remote design [23] will be useful as a starting point for the following editions of the HCI course. Social communication channels played an important role in the design experience; in the next edition of the course we will try to expand further their use and to have a better comprehension of the complementary social tools used by students for group communication. Finally the collaboration with the University of Toulouse was very useful for having an external expert point of view about the results of the process. The collaboration will have also an educational follow-up with the PhD students of the French University, scheduled for the summer 2016, with a workshop on eco-feedback that will start from the results of the experience of the undergraduate students of Venice.

**Acknowledgments** We would like to thank Prof. Emmanuel Dubois and his group at the Université Toulouse III - Paul Sabatier for taking part to the final evaluation of the course's projects.

## Appendix

### A.1 List of bibliographic references given to students

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### A.2 List of eco-feedback products and online services given to students

- 4Noks, http://www.4-noks.com
- Current Cost, http://www.currentcost.com
- Ecodhome, http://www.ecodhome.com
- My Current Cost, http://my.currentcost.com
- OWL, http://www.theowl.com
- PVOutput, http://www.pvoutput.org
- Solarbook, http://www.solarbook.it
- Wattson, http://smarthomeenergy.co.uk/wattson-energy-monitoring

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### A.4 List of additional commercial products, projects and online services added by students

- Clima + SolarEnergy, http://www.micro-solution.it
- Ecofeedback, http://ecofeedback.ca
- Ensemble Water Display, http://www.greenenergyoptions.co.uk/products-services/visibility/ensemble-water/
- GateEnergy, http://www.gateenergy.it
- Home Energy Monitor, http://www.sitecom.com
- OMeter and OBox, http://www.overtechnologies.com
- OpenEnergyMonitor, http://openenergymonitor.org/emon/
- Power-line communication, https://en.wikipedia.org/wiki/Power-line_communication
- Tosca, http://www.domologica.it

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