



HAL
open science

Ergonomics in design and design in ergonomics: Issues and experience in education

Stéphane Safin, Pinky Pintus, Catherine Elsen

► **To cite this version:**

Stéphane Safin, Pinky Pintus, Catherine Elsen. Ergonomics in design and design in ergonomics: Issues and experience in education. *WORK*, 2020, 66 (4), pp.917-931. 10.3233/WOR-203237. hal-03079948

HAL Id: hal-03079948

<https://hal.science/hal-03079948>

Submitted on 17 Dec 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Ergonomics in design and design in ergonomics: Issues and experience in education

Stéphane Safin^{a,*}, Pinky Pintus^b and Catherine Elsen^c

^a*i3-SES, CNRS, Télécom Paris, Institut Polytechnique de Paris, France*

^b*Ecole Supérieure des Arts (ESA) Saint-Luc, Liège, Belgium*

^c*LUCID, Faculty of Applied Sciences, University of Liège, Belgium*

Received 22 May 2019

Accepted 1 February 2020

Abstract.

BACKGROUND: Articulating design and ergonomics skills through education is a major challenge for both fields. Indeed, professional ergonomists are increasingly deeply involved in design processes, and ergonomics education should train them in design skills. As courses in ergonomics education are often time-constrained, it is difficult to mobilize students in real-scale projects and to involve them in design processes. Conversely, activity analysis and active involvement of users in design projects (through co-creation or co-design processes) are rarely convened in architecture and design curricula.

OBJECTIVE: It is therefore necessary to develop effective and relevant pedagogical settings, enabling students of both fields to develop their abilities and equip them to act in concrete design situations.

METHODS: In this paper, we describe a large-scale pedagogical setting involving groups of students from different disciplines gathered around a real-scale design project (re-shaping the waiting room of a mental health center). The ergonomics students' main task is to analyze the needs and real activities of end-users; the interior design students' task is to produce the design project. This communication more precisely focuses on describing the ergonomics students' fieldwork and the practical and pedagogical innovations put in place to help them face the various challenges encountered during the project.

RESULTS: Based on formal feedback from students, teachers and stakeholders, we address three main challenges: (1) dealing with the temporal constraints of the intervention, (2) documenting and observing a sensitive situation and (3) involving end-users to place them at the core of the design process. For each challenge, we describe the issue at stake, the work conducted to deal with this issue, and eventually the feedback collected from students, teachers and stakeholders.

CONCLUSION: The paper concludes with an analysis of success and failure factors for such pedagogical settings, in particular for physical enquiry devices, co-creation processes, and co-constructed pedagogical settings. It shows the impact of these settings for students, but highlight that collaboration between ergonomists and designers is a key issue for learning in a positive experience.

Keywords: Creativity, design education, co-creation workshop, physical enquiry, co-constructed pedagogical setting

1. Introduction

It is well-known nowadays that both design and ergonomic skills are essential in order to conduct efficient design projects, based on properly

*Address for correspondence: Stéphane Safin, 19 place Marguerite Perey, 91123 Palaiseau Cedex, France. Tel. : 01 75 31 98 71. E-mail: stephane.safin@telecom-paris.fr.

documented empirical data. Yet, how to articulate these skills, especially through education, still lacks clarification. This paper thus addresses three crucial, intertwined issues: (1) training ergonomists to intervene in design projects, (2) training designers to mobilize ergonomic empirical approaches in their projects, and (3) training both to collaborate with each other. Although these issues are essential for the education of young ergonomists and professional practitioners, one has to observe that French and Belgian ergonomics training courses devote little time to immerse students in real-scale design projects. Conversely, activity analysis and active involvement of users in design projects (through co-creation or co-design processes) are rarely convened in architecture and design curricula. As courses in both fields are often time-constrained, it is indeed difficult to involve students in real-scale projects while engaging them in testing different empirical methods. It is therefore necessary to develop effective and relevant pedagogical settings, enabling students to develop their abilities, and equip them to take action in concrete design situations. This communication builds on this observation and paves a way towards this goal.

In this paper, we describe an interdisciplinary teaching experiment conducted in Liège, Belgium, where ergonomics and interior design students were fully immersed in a real project, while collaborating with each other and learning from their different, but complementary, viewpoints. To do this, we seized the opportunity on a real site, spanning two academic years, and brought together students of various backgrounds in order to address the issue in complementary ways. The project started with a broad exploration of the problem and led to the concrete delivery of a chosen solution on the construction site. Our communication focuses on both the ergonomists' and interior designers' involvement in the project.

In the first section, we briefly discuss the links between architectural design and ergonomics, and the pedagogical implications. We then address three setting challenges students had to face, namely (1) the time-constraining characteristics of the ergonomic intervention process, (2) the documentation and observation of a sensitive situation, related to mental health and (3) the involvement of end-users at the very heart of the design project. We detail the original solutions brought to address these issues, respectively: co-construction of the intervention by students and teachers; close collaboration between ergonomics and interior design students; mobilization of physical enquiry devices and the set-up of an original partici-

patory co-creation workshop. We enrich each section with feedback provided by the various stakeholders.

2. State of the art

2.1. *Ergonomics in design – design in ergonomics*

While the fields of ergonomics and design have been brought closer together in recent years, and the link with design has been at the very core of the ergonomics discipline since its inception, the explicit claim of the central role of ergonomics in innovation and design projects remains relatively recent [1]. It is therefore necessary for ergonomic practitioners to go one step beyond the high-level, abstract recommendations or formal use scenarios they traditionally formulate. As design projects grow more complex and systemic, the mere correction of existing solutions and the criticism of projections made by others are no longer enough. For ergonomics propositions to be heard by design collectives, recommendations need to be substantiated in concrete proposals (i.e. to be supported by specific examples), conveying both implicit recommendations and practical exemplifications. Ergonomists must therefore urgently be equipped to deal with unknown design areas and complex, ill-defined design problems.

Moreover, the field of design has become significantly closer to the concerns of ergonomics over the last few decades. The place of the users as well as a certain form of empirical approach in understanding their activities have indeed been more and more precisely formalized in design. Disciplines such as product, service or software design progressively shifted over the past four decades from “usability” to “user-centred approaches” and eventually to “users-driven experiences” [2]. Fields such as User-Centred Design (e.g. Vredenburg, [3]), Interaction Design [4] or Design Thinking [5] have blossomed, given the growing implications of user-driven approaches in product design [6]. Likewise, fields such as service design, marketing and even management, continue to take inspiration from the human and social sciences to develop new ways to deal with contemporary challenges [7]. Therefore, one has to observe that designers tend to expand their roles towards tasks traditionally carried out by ergonomists.

Yet, while design essentially claims an empathic posture, explicitly mobilized in methods such as Design Thinking (and sometimes supplemented with

derived forms of ethno-methodologies), ergonomics is based on a rigorous, precise, and structured empiricism. Designers, and more specifically architects, are trained to transform “needs” into spaces, but are not specifically specialized in identifying these needs. Ergonomists, on the other hand, use a battery of methods to identify “needs” or “spaces of possible future activities” [8], without, however, developing in their curriculum the ability to shape their “recommendations” into concrete outlines of solutions. In short, while the designer’s observation aims to provide him/her with inspiration or intention for the project, the ergonomist aims, to a larger extent, at providing scientific evidence supporting this intention.

In this paper, we consider this link between ergonomics and design to be an essential condition to insure end-users a central place throughout the entire design process [9]. We are indeed convinced that, like Sanders and Stappers [10], the future of design lies in the participation of users during design *ideation*, and that ergonomists have a specific role in this implication.

In order to strengthen the link between both disciplines, we argue that there is a need to shift the dividing-lines between them, enabling the designers to plunge into empirical data and enabling ergonomists to be fully involved in the design process. In order for these skills to take root, it is essential to first implement them in the curricula. To this end, we have developed an original pedagogical setting, based on a practical exercise, a concrete project and strong collaboration between students in interior design and ergonomics.

2.2. Implementing a studio setting in ergonomics through socio-constructive learning

The pedagogical setting described in this paper is rooted in a form of socio-constructivism (inspired by the work of Bruner [11] or Vygotsky [12]), and is based on several features, each defined in terms of pedagogical objectives.

Firstly, learning requires an active role on the part of students, especially in the field of design, where professional skills call for a large proportion of implicit knowledge and know-how [13]. In this case, active, project-based learning with efficient orchestration by the teacher is recognised to be relevant [14]. The design domain has thus a long tradition of implementing *design studios*, where students autonomously produce design solutions for real or close-to-real problems, with teacher(s) regularly

providing constructive feedback, mostly verbally, on students’ work [15, 16]. Such a studio setting encourages students to develop a process of reflection-in-action, which is an important component of professional design processes [17]. Although the studio setting is largely used in design curricula, it is less the case in psychology and ergonomics training, where courses are often more theoretical, and where case-based reasoning is usually disconnected from real situations.

Secondly, since ergonomics in design requires a major part of collaboration with other projects’ stakeholders (designers, users, clients, etc.), it is important to establish a collective setting. This enables co-construction of meaning, especially in open-ended learning situations, where students can help each other to acquire skills (within their Zones of Proximal Development, as defined by Vygotsky [12]). Moreover, collective argumentation processes can help deepen the understanding of problems and solutions [18]. Such collective settings might generate *sociocognitive conflicts*, as commented by Perret-Clermont [19], i.e. students may make cognitive progress by confronting their viewpoints and striving to resolve their divergences.

3. The pedagogical setting: Structure, goals, methods and results

3.1. Global project structure

The pedagogical setting aims to involve students from different backgrounds (ergonomics and interior design) around a real-scale healthcare design project. The chosen site is the waiting room of a mental-health-care centre in the Liège (BE) area, which requires certain architectural redesign. This concrete situation offers several added values. First, the scale of the project is particularly appropriate, the reduced size of the space allows the design project to be realistic enough given the limited time scale of the educational setting (30 hours for the students in ergonomics, 60 hours for the students in interior design). Second, the project is rooted in the mental health field, which renders the students’ involvement from various fields relevant, including psychology-related disciplines. Third, the problem is rich enough to require an ergonomic intervention in order to fully understand the variety of situations at stake, as well as to analyse the complex activity of the different users (patients, health staff, and administrative staff).

3.2. Educational goals

The time span devoted to the ergonomists' intervention has been limited to roughly 30 hours, given the academic framework of their class, entitled "Design Ergonomics and Creativity". In this very short time frame, teachers pursued the following pedagogical objectives for their students:

- Discovering the design process, its main complexities and the role ergonomics can play (acting *on* the project and *in* the project, e.g. Béguin [20]);
- Collectively constructing and carrying out an upstream ergonomic intervention with regards to a concrete design project, including an important empirical field approach in order to analyse real situations and needs, and feeding the design process with relevant input;
- Working closely with designers and developing useful skills and abilities to take action in multidisciplinary contexts.

For the interior design students, their class, entitled "Research and Project", spanned roughly 60 hours of supervised sessions and had the following pedagogical objectives:

- Learning to collaborate with other stakeholders (professional or students);
- Learning to organize the work within one's own group ("intra-collaboration") and with students from various backgrounds ("inter-collaboration");
- Learning to participate and to co-construct with others, specifically clients and end-users;
- Carrying out a project on a real-scale field, until its implementation.

3.3. Educational methods

The main difficulty of both educational settings lay in the balance between their real-scale, real-time ambitions and the limited temporal resources at hand. Reaching this delicate balance required building an efficient, fast, and relevant process in which students were directly involved in hands-on, rich learning situations.

To this end, the ergonomic intervention was co-constructed right from the start by the teachers and the entire group of ergonomics students (nine students). This co-construction, which enabled the students to appreciate the stakes of an ergonomic intervention

and the constraints of a real-scale design project, was fuelled by rich debate over the right methods to use. The complementary expertise of the teachers (one with a background in ergonomic psychology and another in architectural and building engineering) also helped save time and consider the practical constraints of the intervention, which were not always clearly identified by the ergonomics students. The joint implementation of a single intervention was chosen, rather than work conducted in subgroups, keeping in mind the need to efficiently pool resources to ensure a consistent empirical documentation of the situation while dealing with low time volume and limited access to the research field.

The ergonomics students used different complementary methods and made several significant contributions to the design process:

- through a state-of-the-art research, they searched themes that could refine their understanding of the formal demand (for instance about "snoezelen spaces", interior architecture of tiny spaces or affordances) and created a list of criteria that could inspire the project;
- they designed a stakeholders' mapping, conducted six in-depth, semi-structured interviews and an original patients' survey (through physical enquiry, see below), which allowed them to build a list of issues relevant for the design process, as well as to document preferences, direct and indirect suggestions from patients and staff members;
- they conducted *in-situ* observations that facilitated the fine understanding of the local situation. These observations enabled the drawing of a model of the reception path in the health centre, and structured the mapping of staff members' and patients' micro-scale activities.

The project thus enabled, in a relatively short time, to involve ergonomists students in tasks similar to the ones conducted in professional settings [8, 20, 21].

As for the interior design students, the class was organized in 10 distinct sessions. Among those, five gathered only the interior design students and their teacher and aimed at reviewing the on-going project and its evolution. As for the five other sessions, the first was devoted to introducing the project; another was a theoretical session addressing collaborative practice and how to implement it; another briefly presented ergonomics and activity analyses, and the last two spanned the co-creation workshop (described below).

Class sessions for the interior design and ergonomics students were thus organized separately, given institutional and timetable constraints, but also because the students organized several informal collaborative sessions (to pool information, co-construct field work, etc.).

Moreover, the students collectively designed a co-creation workshop, which lasted about four hours, and gathered all the stakeholders (students from both groups; teachers and health-care centre staff members). This enabled a detailed sharing of points of view on three possible areas of creative exploration, all pointing to various alternatives the project could lead to. This co-creation workshop is described in detail below.

3.4. *Results of the design project*

The project request (initiated by the health care centre director) was to re-design the centre's waiting room, i.e. a short and narrow entrance hall mainly used by patients coming in for consultations. The project quickly widened to the entire ground floor as the process proceeded. Students from both groups observed that staff members also used the space devoted to this waiting area to walk through and gain access to other connected rooms and functions, which gave rise extending the design process to the entire floor. The field work revealed that the waiting area was not only a space to "wait", but also a central place for spatial circulation, in close connection with the activities of taking appointments, including crossing paths with other patients and health care professionals and close interaction with the secretariat. The project also extended towards the first floor, hosting the consultation rooms, down to the cellar, which use and access were also part of the staff's daily routine, and back to a small garden, including a short building extension used by the secretariat as well as the archive room and the staff kitchen area. A global analysis was therefore conducted in order to welcome and ensure the wellbeing of all user types (including the staff and its day-to-day working comfort), every individual being considered as a crucial part of a larger system in operation and interaction, where none of the sub-components should be ignored.

The project thus expanded, and was nurtured by the co-creation workshop presented next. For instance, one of the co-creation workshop's outputs translated into a design intervention conducted directly on the staircase (colouring the stair steps to extend the welcoming area to the upper consultation rooms).

As for the final execution, the entire pedagogical setting has enabled the health care centre to promote the project to its board of directors and to obtain additional financial support, enabling a larger building site (a project on the entire ground floor).

4. **Research questions and methodologies**

We adopted an ethnographic bottom-up approach to define and address research questions emerging from the pedagogical setting described above. Based on observations, we identified three key challenges students and teachers had to face, for which original responses have been designed, and which could be of interest to Design and Ergonomics Research and teaching communities, namely:

- Helping the students manage a rich, real-scale experience given the very limited time span for the courses, and the fact that the ergonomics students have no previous experience in design-related fields;
- Empirically documenting a potentially sensitive situation, given our educational context, namely the waiting room in a mental health care centre, where patients may suffer from various and serious mental pathologies;
- Involving users (here, health professionals) at the core of a design process.

These three challenges are detailed in the following sections, and include a brief contextual description of the issue at hand, an outline of how each was dealt with, an assessment of the solution, and perspectives for further improvements of our pedagogical setting.

In order to assess the pertinence and efficiency of the proposed pedagogical solutions, we gathered information from five complementary sources. First, feedback was collected through informal discussions with the stakeholders (staff members and students) at the end of the co-creation workshop. Second, a formal assessment of the entire setting by the involved teachers (N=3), co-authors of this paper, was conducted. Third, formal feedback was collected from the ergonomics students (N=9) who had to produce a personal written reflective report after the course's end (on average three to four pages for each student). Fourth, the interior design students (N=13) were required to produce written transcripts for each formal class session. Keeping such written records of what was said, done, and observed, helped students to analyse how the project unfolded. Fifth, two

semi-structured interviews were conducted one year after the experiment with two of the participating students, one ergonomist and one interior designer. These 30–45-minute interviews allowed for investigating long-term learning outcomes and explored several themes such as: the most lasting memories after the course; the contribution of the course (and the overall experience) to the general understanding of the chosen curricula and of the chosen career path; the benefits and drawbacks of the entire setting, of the collaboration with students from a different field, of the co-creation workshop involving all stakeholders, and of specific aspects of the setting (such as the physical enquiry task, the content co-construction with the professors, etc.).

5. Results section #1: The construction of the setting, given the high temporal constraints

5.1. Issues

We focus here on the issue of time seen from the ergonomics course perspective, as the pedagogical setting organized for the interior design students unfolded as a regular design studio and relied more on off-class personal work than on classroom teaching, and therefore suffered less (or differently) from the time constraint.

As explained earlier, the time span for ergonomics students is a 30-hour classroom setting, completed by personal work between classes. This setting is very limited, given the ambitious pedagogical objectives: discovering design, learning to collaborate and managing the field intervention, and specifically intervene in regard to ergonomics principles, i.e. heavily relying on empirical data, which is very time-consuming to gather. Considering these objectives, the challenge is to build an ergonomic intervention in a design project with a short temporal scale, in which students carry out empirical work, build a multidisciplinary collaborative approach, and fully participate to the design project.

5.2. Proposal

The proposals for the time constraints are three-fold. First, as there was some flexibility in managing the class schedule, we defined intensive two-day sessions with students and teachers, spread over a full semester, instead of teaching two hours a week. This offered more time for empirical, iterative field studies

between each session. Moreover, intensive sessions allowed more time for the definition of empirical methods and providing feedback on observations.

Secondly, in order to maximize students' involvement and to foster learning about issues related to ergonomics interventions in design projects, the setting was fully co-constructed by both teachers and students. Such co-construction constitutes a risk for teachers as it impedes any precise planning before the beginning of the course. To reduce this risk, specific orchestration activities [14] were managed by the teachers, before and during each session. Before the course, the main challenge was to anticipate logistical constraints (observations and interviews on field, scheduling collaborative processes and principles, etc.), in order to ensure the endorsement of all stakeholders and to limit the risks of time-consuming misunderstandings. The teachers moreover conducted a fairly detailed analysis of the context prior to the course and designed an overall structure of the pedagogical setting as well as the planning of the sessions in close collaboration with the interior design teacher. During the course, the focus was rather on helping the students to build pertinent actions: bouncing back on sound reflections, moderating students' methodological design processes, highlighting pertinent reflections and observations, ensuring involvement in co-constructed methods, and so on.

Thirdly, in order to plan relevant on-field interventions in light of the limited temporal resources and access to the field, we arranged for close collaboration between ergonomists and interior designers. While the students engaged in an iterative process consisting of short empiric phases on the field (followed by rapid analysis to document the target situations), they also frequently conducted face-to-face or online meetings with the interior design students (in order to adapt empirical methodologies with regard to the interior designers' needs and first design ideas, and vice-versa). This coupling was conducted very tightly to ensure the collected data to be of real use for the design process, the interior design students being themselves involved in some field observations. And while the addition of collaborative meetings reduced their formal, academic character and helped save time, they also ensured a common understanding of each other's respective constraints. The interior design students were, in this way, able to grasp the stakes, methods, and benefits of an ergonomics intervention, while ergonomics students were able to get to the heart of a design project, to grasp the ins and

outs, and to understand the process dynamics. Establishing this common understanding constitutes one of the most complex educational objectives to be pursued and is very much dependent on the students' motivation and willingness to cooperate.

5.3. Feedback

Globally speaking, the above-mentioned propositions are deemed efficient. In their transcripts, the interior design students praised the richness of working in close collaboration with ergonomists, and how this collaboration along with their direct participation to field observations helped them to understand the issues and the iterative added value of an ergonomic intervention. The interviewed interior designer commented, "It was really interesting to work with other students, other than interior design students, who were also confronted to the question of adapting an environment to the person, but in a different way. This overlapping of perspectives, it was really what attracted me the most in this course".

Before any encounter with the ergonomists, these students had been sensitized to the challenges of collaborative design and to the necessity to opt for a "meta" point of view while working in larger groups. They were also invited to conduct deep context analysis themselves, but the expertise and scientifically rooted methodologies of ergonomics students supported their own approach. The interviewed interior designer noted, "What ergonomists brought to us, it was more about the acquisition of a methodology to conduct field work. They showed us how to do, to apply such a method that we had previously never learnt".

Such a multidisciplinary collaboration, involving students from various disciplines on a single project, helped them all to mutually understand the extent (and limitation) of their own skills and to identify why, and how they might need each other's expertise. As mentioned by the interior designer students, "Together we moved forward at a slower pace, but better".

The ergonomics students, in their written reports, spontaneously mentioned several points. Seven out of nine students stressed the difficulties related to the project's temporal constraints; the timing was considered globally too short given the scale of the project, the sessions too rhythmic, and this temporality was hardly compatible with the calendar constraints of the interior designers and field partners.

Concerning the collaboration, relations with interior design students were judged in a very positive way by eight out of nine students, although some of them (N=3) pointed out difficulties of coordination, genuine collaborative work starting too late in the project (N=3), and collaboration somehow unilateral (N=1), as one student regretted not having been involved slightly more in the design of the project before the co-creation workshop. Organizing collective work with nine peers was considered globally unusual and complicated by six students; although two students felt that it was rich and worked well.

Regarding the educational structure of the course, four students underlined the interest of having a non-directive accompaniment and spaces of freedom, where the teachers "alternate between two postures: peers and experts", enabling them to build their own methodologies and data collection tools as professionals would do. The interviewed ergonomist mentioned "a sense of equity, with regard to what you can offer as a student, interesting for the other students and even for the teachers". Nevertheless, two of them pointed to the lack of information clarity when it came to professors' expectations and two others expressed difficulties with regard to the coordination with teachers between two intensive sessions. The students observed that it would have been helpful to more frequently assess and validate intermediary steps of their intervention, in order to re-orient them more efficiently in the case of imprecise methodological drafting.

5.4. Perspectives

Considering this feedback, several improvements have to be made on the setting. First, as learning about ergonomics interventions requires a great deal of input from the teachers, the overall schedule has to be redesigned by multiplying one-day intensive sessions (instead of three two-day sessions), thus providing the students with more regular feedback in between field sessions.

Second, the professors should provide more explicit explanations on their expectations, as well as the potential added value of each deployed methodology. For instance, ergonomics students designed personas (on basis of their field data) and later considered them of limited use, as the interior design students did not explicitly refer to those personas during their final presentation. Personas, yet, have been pointed out by interior designers in their tran-

scripts as particularly important as they shaped their understanding of the needs of various stakeholders. Teachers should therefore make a clearer point about which methodology might be useful at which step of the process, and with respect to which goal. In the course preparation, teachers should also pre-select and frame the variety of methods to be used, in order to focus on the co-construction with students on specific methodological details.

6. Results section #2: Documenting a sensitive and complex situation

6.1. Issues

The project involved the observation and documentation of the particularly sensitive and complex situation of patients with mental disorders waiting in a tiny entrance hall before consulting a therapist. Direct observation was deemed impossible because the space was too small and the population difficult to observe. Interviews raised delicate questions of privacy, while questionnaires had already been once distributed in the past (by the health care centre staff) but without success. Moreover, students could not access the site as often as they had wished; the staff members, for the sake of their patients' wellbeing, decided to limit entrance to two students at a time, for short periods of time, and required students' coordination in order to avoid repeated solicitation (i.e. stress, fatigue, and work overload for field partners). Considering this particular context, it was challenging to determine how the students could empirically document, in a nuanced and pertinent way, such a potentially sensitive situation.

6.2. Proposal

In order to collect useful data for the design process while proposing an engaging participatory vector for the people, and without interfering too much with the local situation, a tangible and situated format of data collection was proposed which we coined a "physical enquiry". This approach, following the trend of data physicalization (e.g. Huron et al., [22]), consists of transforming intangible data into tangible, easy to handle, observable and engaging objects. In this context, the students created several rudimentary devices (see Fig. 1 a, b, c) that were placed in the waiting room for a week.



Fig. 1. (a) Overview of the whole installation. (b) Physical panel asking patients to evaluate possible ambiances of waiting rooms. (c) Device for collecting information on the time spent in the waiting room.

Four devices addressed three specific questions:

- The first aimed to determine the time spent by patients in the waiting room. For this purpose, five small boxes were designed, and each one were labelled with a time span. A box of small tokens was provided (Fig. 1.c). Patients, when leaving the centre, were invited to put a token in the appropriate box depending on the time spent. This data was later compared to information collected by the secretary, who had been asked to

identify roughly how much time each patient had spent in the waiting room;

- The second question was to address the ambiance appreciated by patients in the waiting room. Students designed a panel displaying several pictures of waiting rooms and spaces, corresponding to different ambiances. Patients were invited to put a sticker in front of the different photos, according to whether they judged these atmospheres pleasant or not;
- The third question was about the activities patients were doing while they waited. A set of images about different expected activities (using a phone, reading, talking, listening to music) was displayed, and people were invited to draw a cross under images corresponding to their activities. Blank spaces were also left for patients to write other activities;
- A classic suggestion box was also proposed, to allow people to leave qualitative comments or suggestions.

The setting was installed on site over a four-day period. Out of the 70 patients who were present in the waiting room (as counted by the secretary), students gathered 10 responses about waiting time, 32 for ambiances, 10 for activities and 5 suggestions.

6.3. Feedback

While we had hoped for a higher quantity of responses (e.g. only 14% of patients answered the question about the waiting time), according to the health professionals the presented devices enabled patients' engagement, which is generally difficult to obtain by other means. The design of these devices and the following data analysis was no more complex than for a questionnaire. The students were able to experiment with this innovative way to collect data, which was compatible with the temporal, pragmatic, and ethical constraints related to their specific field.

The staff members and teachers considered that many additional similar efforts could be made to improve data acquisition; students proposed only very rudimentary, hand-made devices. From teachers' point of view, students could have offered more elaborate, visually convincing physical devices.

In their individual reflective reports, five students positively mention physical inquiry devices, although three students wished more time could have been allotted to the development of the devices and the data collection.

6.4. Perspectives

In contrast with classic questionnaires that require answers to questions that are uncoupled from the artefacts or systems they focus on, the idea behind "physical enquiry" is to have a *situated* enquiry. Thus, physical enquiry devices can be displayed onto objects, facilitating situated and contextualized reflection from the respondents.

Considering this, perspectives will be threefold. First, we will investigate how physical enquiry may support emotional expression; engaging people with objects instead of words opens interesting possibilities in terms of emotional expressions. For example, feelings about objects or features of a given space can be addressed. Secondly, the balance between public and private dimensions has to be more specifically and systematically addressed. On the one hand, displaying previously given answers can be detrimental to the quality of inquiry, as the lack of privacy could influence responses. On the other hand, publically displaying responses can yield collective expression, debate, and reflection. Thirdly, physical enquiry devices, while engaging, can also be perceived as "childish", especially considering their "quick and rough" visual aspect. It is thus very important, especially in a community of mentally ill patients who suffer from stigmatization, to ensure the devices achieve a satisfactory balance between playful engagement and perceived seriousness, in favour of the legitimacy of the enquiry.

7. Results section #3: The involvement of users directly in the design project

7.1. Issues

The construction of such an intervention requires involving the users at the heart of the project, limited here to health professionals for ethical reasons. Although in a traditional situation, ergonomics students would validate their recommendations with users through formal encounters (interviews and focus groups), it was important here to increase users' level of engagement, notably with regard to the time constraints that did not allow exhaustive empirical studies. As users "own the factual problem" [23], in other words are experts of their own personal experiences and issues associated with their personal situation, their active participation in the project would ease the fine understanding of

their needs, and thus nurture the design decision-making process while empowering them through this decision-making process [24].

It was moreover expected that the increased involvement of end-users would ease the acceptability of architectural modifications, as the interviews with staff members and patients demonstrated a high degree of attachment to the context and some reluctance to see the current situation evolve too much. It is now acknowledged that designers and users are inextricably related with regard to both the design process and the design output. Designers, and especially architects, indeed have a major impact on the quality of the built environment, i.e. on the quality of life of many people. Designed artefacts, on the other hand, become meaningless unless endorsed by end-users (in power of taking ownership or rejecting these artefacts) [25, 26]. If the intertwined relationship between designers and users itself constitutes a crucial part of the design process, involving users in the design process becomes even more crucial to the project success [10, 27], especially in this specific context.

7.2. Proposal

To cope with these issues, the staff members and the students took part in a half-day creative co-creation workshop, which allowed them to be directly involved into the design process. This co-creation workshop mobilized tangible expression supports (1/20 scale mock-ups, inspirational interior architecture magazines, and material samples) prepared in collaboration with interior design students (Fig. 2), which were expected to ease the participation of “unknowing” participants (in terms of architectural expertise) and to push the interaction beyond mere verbal evaluation (as could have been the case if those participants were presented with only 2D representations).

One characteristic of design expertise is designers’ visual way of knowing and working [5]. In architecture and other design disciplines, it is quite standard for designers to heavily rely on the use of external, or “intermediary” representations (sketches, CAD representations, 3D models, etc.) as aids to communicate ideas both to themselves and to others [28, 29]. Yet, in anticipating how future spaces will be experienced, architects and interior designers have limited capability to test them full-scale. While in industrial or product design full-scale prototypes are frequently used to assess users’ reactions and behaviours, their

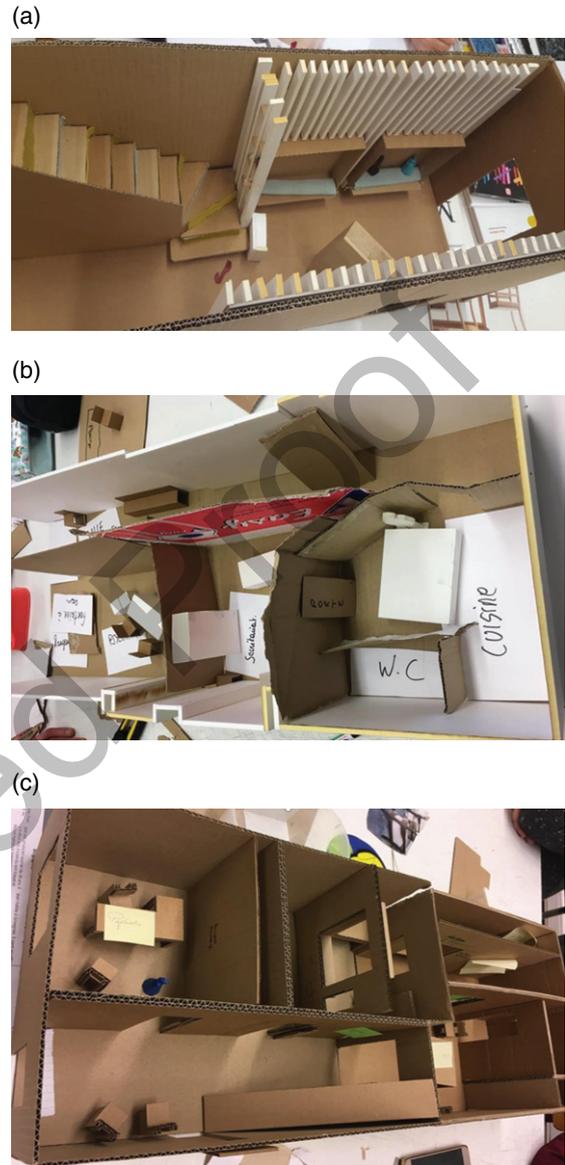


Fig. 2. Mock-ups for each of the three scenarios before the workshop.

use is less compatible with the design of large-scale artefacts such as inner and outer spaces. Among the available external representations, 1/20 scale physical mock-ups are generally considered as particularly pertinent to engage non-designer stakeholders and to better understand users’ experiences during their co-construction [30]. It also allows for debates on users’ past work experiences and for the development of activities conjointly with the development of the design project [31]. This type of setting has already been mobilized previously [32, 33] and has

indeed shown its effectiveness in supporting interdisciplinary collaborations for space design.

This workshop brought together three groups, each composed of interior design students, ergonomics students and mental health centre professionals. Each group was invited to contribute to the project in three different steps, defined according to three scenarios, each step corresponding to a pre-built mock-up made by the interior design students and offering different degrees of abstraction.

The first constrained scenario envisioned a re-design process limited only to the waiting room area (as suggested in the project original brief). At the time of the workshop, the interior designers had reached quite a complete design proposal and the mobilized mock-up had thus a relatively high level of detail and realism (see Fig. 2a). The second scenario, on the other hand, suggested a constraint-free, idealistic situation; the ground floor of the building could be entirely re-modelled, without considering the building structural constraints nor the costs. The goal here was to deepen the understanding of the needs of the users. During the workshop, the mock-up provided by the students was rudimentary (Fig. 2b), and the project was poorly defined, leaving much room for ideation. The third scenario was the intermediary between the first two; in this case, it was possible to freely shuffle all the functions between spaces of the ground floor without affecting the structure of the building. The model was also relatively incomplete and welcoming large modifications (Fig. 2c).

Each group collaborated during three 45-minute sessions. In each session, each group focused exclusively on one of the three above-mentioned scenarios, and the groups moved from one project to another between the sessions. Participants had to reflect on the project at hand by modifying the in-process mock-up, sometimes pursuing the work started by the previous group(s). Thus, each participant was invited to work on each of the three propositions.

7.3. *Feedback*

The work on physical models proved to be effective in substantiating or representing, concrete proposals, but also in discovering unsuspected contextual aspects, unexplored constraints as well as in bringing out elements related to the users' work activity which had not been previously identified. The open, scalable and easy-to-handle nature of the mock-ups triggered participation of all stakeholders, and not only the designers who are used to represent the spaces and to

work on them. Ergonomists and users have thus been able to have a better understanding of the spaces and the design proposals, and to contribute to the different projects, in addition to the simple evaluation of suggested proposals. The transposition of their suggestions and ideas directly into materiality enabled them to confront those ideas themselves, to assess their relevance and realism, and to consider other points of view. In other words, their personal handling of the various mock-ups helped them manage the complexity of thought [28, 29] and, in doing so, allow for the whole project evolve. That being said, the most interesting insights for the design process did not lie in the concrete proposals, but in the discussion process supporting the project co-creation. A post-analysis of the videos recorded during the workshop allows for identifying and listing concrete proposals, but, more importantly, the arguments behind these proposals. These arguments can be grouped and compared in order to compile a list of users-requirements (or design criteria), which can be later re-used by the designers.

Involving not only staff members in the co-creation, but also ergonomists and interior designers, supported fruitful debate based on complementary viewpoints; which is crucial to allow for the design process to evolve [26, 36]. Users brought their feelings, opinions, and embodied knowledge of the situation and activities to the table; ergonomists provided more formal knowledge about the activities occurring in the space, as well as their personal opinions; and designers contributed their sensitivity and technical knowledge as well as their previous reflections on the design project. The interviewed ergonomists stated, "At some point, we debated our real purpose in the project. We wondered: 'What are we really useful for, in the end?'. And during the workshop we realized: 'Oh, yes, in fact we can contribute with our own experience, not even as ergonomists, but simply as human beings'". As for the interior design students, the interviewed designer added, "For us, this co-creation workshop was also a foretaste of what we experience as professionals because... we are confronted with this kind of situation all the time, making the link with the customer, the one who asks us to arrange something, and the user, the one who will really be impacted by the project". With respect to how ergonomics students specifically contributed, one of the interior design students relates in the transcripts, "The ergos [i.e., the ergonomics students] help us identify the weak points of the project; they give us attention points

and advices. We go into more detail, the contribution is constructive and bilateral, as there is an exchange of knowledge”.

The three models were of a different level of completion and accuracy. We observe, interestingly, that the simplest model and the least developed scenario (Fig. 2b) were the most conducive in generating rich discussions, engaging everyone in generating innovative proposals. There are two likely explanations. First, the granularity of the model may have an influence on the way it is, in itself, understood and mobilized by the stakeholders (especially laypersons in design). In the domain of architectural plans, it is recognized that sketchy representations (less accurate, less complete) are judged more open, less finite and more effective supports for creativity than conventional CAD representations [37]. The second explanation may relate to the definition of the design problem; working on a single waiting room space may be over-constrained, and not supporting rich discussions, whereas the other briefs opened a larger space of exploration with regard to the right level of constraints.

In their reflective reports, six out of nine of ergonomics students mention the positive aspects of the co-creation workshop. It was considered an effective way to materialize and embody their ideas, it allowed for deep, multidisciplinary exchanges and was an appropriate culmination point, which nicely concluded the empirical research. The interviewed ergonomist pointed out that “it was the best part of the entire course [. . .] it was really interesting to see the different points of view. It helped us create some complicity [. . .], helped us create something together, something we completely adhered to. At the end, we all really wanted the project to evolve in the way we had imagined it [. . .] this is the phenomenon of building something together”. Two students regretted not having taken a more active role in the preparation and running of the workshop itself.

Another interesting added value was identified by the health care centre director, who stated, “The co-creation exercise between my team and your students was very interesting. It enabled us to get invested in the project, to create cohesion within the team, but also to appropriate the imagined space. [. . .] The final project we will implement is the result of all the shared thinking. The really surprising thing was how quickly we reached a general consensus” (extracted from a letter sent by the centre director). The co-creation workshop, its external representations and its process thus supported the collective

construction of knowledge and enhanced the project’s acceptability.

7.4. Perspectives

Several perspectives are necessary if the co-design workshop is replicated in the future. Firstly, the mock-ups, while considered an efficient support for the concretization of ideas and for collaborative multidisciplinary work, could be completed with other forms of representation. The observed design activity indeed mostly limited to re-arrangement of pre-existing components (e.g. furniture) coupled with verbal comments. Other modes of representation may trigger complementary reflections [32] such as sketching, immersive 3D models, mood-boards, modelling clay etc. may indeed support other design processes, as different representations evoke different kinds of properties of the architectural object [38]. Research still has to be conducted on the articulation between different representational objects as the support of design processes, especially with non-designers.

Second, organizing this workshop on-site, rather than in a classroom, could truly enhance the reflective quality. We have demonstrated in other work [39] that different modes of representations, as well as the real space to be re-designed, are used as complementary references to support collective discussion in design.

Thirdly, the schedule of the workshop should be redesigned to support continuous reflection on the project, on a slightly larger time span, in order to involve deeper and wider design reflections. Sessions were indeed a bit too short to handle complex design problems. In particular, moving from one project to another was deemed quite inefficient; stakeholders only had 45 minutes to understand the current, on-going, project as well as complete it. The co-design workshop structure should therefore evolve into longer working sessions on a single setup.

8. Global critical feedback from the project’s stakeholders

At the end of the project, each stakeholder was invited to openly share their feedback about the entire design process and/or pedagogical setting.

The mental health care centre staff considered the students’ analyses were relevant and the design proposals appropriate. They especially appreciated being involved at the heart of the project through

the co-creation workshop, and even managed to find additional funding to extend the project's initial scope and to implement some of the students' proposals, as explained above.

From the teachers' point of view, the pedagogical setting was successful. The strengths mainly relate to previously-mentioned key aspects, namely the highly coupled collaboration between ergonomics and interior design students, the co-construction of efficient data collection processes given the time constraints, and the involvement of users at the heart of the design. In particular, the physical enquiry devices and the co-creation workshop proved to be considerably relevant.

Nevertheless, the relevance of the setting could be improved. The physical enquiry devices could have been further developed. Their design could involve a creative design thinking process that is also a part of the ergonomists' training. Given their potential, it would be interesting to spend more time on the development of these devices with the interior design students. Likewise, the co-creation workshop was highly informative and was a nice conclusion to the pedagogical setting. However it lacked structured data collection. A more formal and systematic analysis of the needs, proposals, contextual elements evoked by the users during the workshop on basis of the three mock-ups should have been anticipated in order to further nurture the design project. Conversely, the multiplication of methods mobilized by the ergonomics students induced some superfluous work. The state of the art proposed by the students, for instance, eventually had little impact on the workshop, the project, or the process.

Through their written reports, all the ergonomics students provided a overall positive opinion of the project. They expressed pleasure and pride in having carried out this project. Moreover, all the students spontaneously emphasized the interest and satisfaction of working on a real-scale project. This type of achievement is not usual in their training, and is considered unique and motivating. The interviewed ergonomist commented, "It was an approach that I really liked, and I find it unfortunate that we did not have it earlier at the university [...] it was the course that impacted me the most and which made me learn the most".

With regards to their learning process, four students underlined how they appreciated discovering the field of design "from the inside"; five of them took note on how their knowledge and understanding of the ergonomist's job progressed; three noticed

how the course changed their point of view on the creative process, while four underlined how they learned to collaborate in a multidisciplinary way and how they had the opportunity to integrate and apply more theoretical knowledge gained in other courses.

Yet, in their written reports the ergonomics students underlined three "culture shocks" susceptible to impede their participation. The first shock concerns the project-based teaching methods, which are highly unconventional for these students who are rather used to theoretical, ex-cathedra types of courses. The interviewed ergonomist commented, "There was a lot of complexity to tackle in this course. Realizing that we had to work hard from the very first day... we had to produce something by ourselves... it's something we are not used to. It makes things difficult but help us realize that it is possible to approach a course differently than just saying "let's study by heart and meet in December for the final exam". The second shock relates to the amount of empirical work to be carried out - much higher than in any other course, but also much closer to their future professional realities. The third shock was the co-constructed pedagogical setting, i.e. the fact that students were expected to take an active role in the day-to-day pedagogical design, alongside the professors. The interviewed ergonomist argued that these accumulated shocks might have slowed their participation in the overall project in comparison to interior design students, who were much more at ease with these pedagogical settings, especially the first two contexts. The interviewed ergonomist stated, while reflecting back on the ergonomics and interior design students respective contributions, "I have the feeling they [i.e. the interior design students] brought a lot to the table, that we have brought less... we were perhaps too much in the theoretical approach and uh... it was still too hard for us the take the leap and change the learning method. I think... yes it was a step harder for us [...] as they were directly, already in a learning process like that".

9. Conclusions

Professional ergonomists are frequently involved in design projects. It seems evident that their education must prepare them for it. Design projects, especially in architecture, spread over a great deal of time, appeal to many actors from different backgrounds and are characterized by the co-evolution of the definition of the problem and the solution [5, 27].

As ergonomists bring information, the project evolves and new issues arise. It seems therefore necessary for ergonomists and designers to work together. This is the goal pursued by the educational framework and pedagogical setting described in this paper.

The described project was ambitious and successful from various points of view, especially its main pedagogical objectives, i.e. working in a collaborative and inter-disciplinary way on a real, complex, and sensitive situation, with professional deadlines. From the ergonomics students' point of view, the experience seems to have truly fostered deep learning and the evolution of viewpoints on design and creativity. As for the interior design students, the interaction with ergonomists and the discovery of sound field work methodologies have heavily contributed to their understanding of the users' needs and desires.

Of course, such a setting does not come without coordination challenges. In addition, several improvements can be made in future attempts, particularly with regard to the organization of the different activities and the temporal structure of the setting. These issues, however, seem to be inherent to one of the major pedagogical challenges of the setting itself, that of letting the students build their own design project, side-by-side with their teachers.

Acknowledgments

The pedagogical experiment has been partially supported by the UE INTERREG projet THE !: Technology in Healthcare Education. Authors wish to thanks all the students for their involvement, members of the mental health care centre for their enthusiasm as well as Jean-Philippe Possoz and Roland Juchmes for their help and support.

Conflict of interest

None to report.

References

- [1] Robert JM, Brangier E. Prospective ergonomics : origin, goal and prospects. *Work*. 2009;41(supplement 1):5235-42.
- [2] Barcenilla J, Bastien JM. L'acceptabilité des nouvelles technologies : quelles relations avec l'ergonomie, l'utilisabilité et l'expérience utilisateur ? (The acceptability of new technologies: what are the relationships with ergonomics, usability and user experience?) *Le Travail Humain*. 2009;72:4. Presses Universitaires de France, pp. 311-31.
- [3] Vredenburg K. Building ease of use into the IBM user experience. *IBM Systems Journal*. 2003;42(4):517-31.
- [4] Rogers Y, Sharp H, Preece J. *Interaction design: beyond human-computer interaction*. John Wiley & Sons. 2007.
- [5] Cross N. *Designerly ways of knowing*. London: Springer. 2006.
- [6] Brown T. *Change by design, revised and updated. How Design Thinking transforms organizations and inspires innovation*. HarperBusiness. 2019.
- [7] Olsen TO, Welo T. Maximizing Product Innovation through Adaptive Application of User-Centered Methods for Defining Customer Value, *Journal of Technology Management and Innovation*. 2011;6(4):172-92.
- [8] Daniellou F. L'ergonomie dans la conduite de projets. (Ergonomics in project management). In P. Falzon (ed.). *Ergonomie*. Paris : Presses Universitaires de France. 2004.
- [9] Charrier M. Intégration de l'ergonomie dans le processus de créativité du designer industriel : application à une conception architecturale centrée sur l'usage. (Integration of ergonomics into the industrial designer's creative process: application to a use-centred architectural design.) *Proceedings of CONFERE 2013, Biarritz (FR) 4-5 July*.
- [10] Sanders EB, Stappers PJ. Co-creation and the new landscapes of design. *CoDesign*. 2008;4(1):5-18.
- [11] Bruner JS. The act of discovery. *Harvard Educational Review*. 1961;31:21-32.
- [12] Vygotsky LS. *Mind in Society: The Development of Higher Psychological Processes*. 1978. Cambridge Mass.: Harvard University Press.
- [13] Ledewitz S. Models of Design in Studio Teaching. *Journal of Architectural Education*. 1985;38(2):2-8.
- [14] Hämäläinen R, Vähäsantanen K. Theoretical and pedagogical perspectives on orchestrating creativity and collaborative learning. *Educational Research Review*. 2011;6(3):169-84.
- [15] Goldschmidt G, Hochman H, Dafni I. The design studio "crit": Teacher-student communication. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*. 2010;24(3):285-302.
- [16] Oh Y, Ishizaki S, Gross M, Do E. A theoretical framework of design critiquing in architecture studios. *Design Studies*. 2013;34:302-25.
- [17] Schön D. *The reflective practitioner : How professional think in action*. New York: Basic Books. 1983.
- [18] Schwarz B, Baker M. *Dialogue, Argumentation and Education. History, Theory and Practice*. Cambridge University Press. 2017.
- [19] Perret-Clermont A-N, Pontecorvo C, Resnick LB, Zittoun T, Burge B. *Joining society: social interaction and learning in adolescence and youth*. 2004. Cambridge: Cambridge University Press.
- [20] Beguin P. L'ergonome, acteur de la conception. (The ergonomist, a key player in the design process). In P. Falzon (ed.). *Ergonomie*. Paris : Presses Universitaires de France. 2004.
- [21] Martin C. L'ergonome dans les projets architecturaux. (The ergonomists in architectural projects). In P. Falzon (ed.). *Ergonomie*. Paris : Presses Universitaires de France. 2004. pp. 421-435.
- [22] Huron S, Gourlet P, Hinrichs U, Hogan T, Jansen Y. Let's Get Physical: Promoting Data Physicalization in Workshop Formats. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17)*. ACM, New York. pp. 1409-1422.

- [23] Reymen I, Dorst K, Smulders F. Co-evolution in design practice. In: McDonnell J, Llyod P, editors. *About : Designing. Analysing design meetings*. CRC Press, Taylor and Francis Group. 2009. pp. 434.
- [24] Kumar A, Maskara S, Chiang I-J. Building a prototype using Human-Centered Design to engage older adults in healthcare decision-making. *Work*. 2014;49:653-61.
- [25] Siva JP, London K. Habitus shock : a model for architect-client relationships on house projects based on sociological and psychological perspectives. In *Proceedings of the Future trends in architectural management international symposium*. Taiwan. 2009; pp. 209-220.
- [26] Narimoto LR, Camarotto JA. How do users design? The case of sugar cane harvester machines. *Work*. 2017;57:421-32.
- [27] Lawson B. *How designers think: the design process demystified*. Fourth Edition. Ed. Routledge, Architectural Press. 2005; pp. 321.
- [28] Vinck D, Jeantet A, Laureillard P. Objects and Other Intermediaries in the Sociotechnical Process of Product Design : an exploratory approach, pp. 297-320, in J. Perrin & D. Vinck (eds), *The role of design in the shaping of technology*, COST A4 Social Sciences, vol. 5, Bruxelles, EC Directorate General Science, R&D. 1996.
- [29] Visser W. *The cognitive artifacts of designing*. Mahwah, NJ: Lawrence Erlbaum Associates. 2006.
- [30] Lim YK, Stolterman E, Tenenberg J. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction*. 2008;15:2.
- [31] Bittencourt JM, Duarte F, Béguin P. From the past to the future: Integrating work experience into the design process. *Work*. 2017;57(3):379-87.
- [32] Dorta T, Safin S. A new co-design workshop approach: methodological principles and feedback from an experience. *Proceedings of COOP 2014 Workshop on Collective Creativity*. Nice, France. 2014.
- [33] Dorta T, Safin S, Boudraâ S, Beaudry-Marchand E. (In press). Co-designing in Social VR. Process awareness and suitable representations to empower user participation. *Proceedings of CAADRIA 2019 - Computer assisted architectural design research in Asia*. Wellington, NZ, April 15-18, 2019.
- [34] Kirsh D. Thinking with external representations. *AI & Society*. 2010;25(4):441-54.
- [35] Safin S. *Processus d'externalisation graphique dans les activités cognitives complexes: le cas de l'esquisse numérique en conception architecturale individuelle et collective*. (Graphical externalization processes in complex cognitive activities : the case of digital sketch in individual and collective architectural design). PhD Thesis, University of Liège, Belgium. 2011.
- [36] Détienne F, Martin G, Lavigne E. Viewpoints in co-design: a field study in concurrent engineering. *Design Studies*. 2005;26:215-41.
- [37] Hannibal C, Brown A, Knight M. An assessment of the effectiveness of sketch representations in early stages design. *International Journal of Architectural Computing*. 2005;3(1):107-25.
- [38] Van de Vreken A, Safin S. Influence du type de représentation visuelle sur l'évaluation de l'ambiance d'un espace architectural. (Influence of the type of visual representation on the evaluation of an architectural space's ambiance). In *proceedings of the conference on the IHM 2010*; pp. 49-56.
- [39] Safin S, Lesage A, Hébert A, Kinayoglu G, Dorta T. Analyse de référents de l'activité de co-design dans un contexte de Réalité Mixte. (Analysis of referents of the co-design activity in a context of Mixed Reality). In : dans Hachet M, Roussel N, editors. *Proceedings of the 25th conférence on l'Interaction Homme-Machine, IHM*. Bordeaux, France. 2013; pp. 23-32.