

## COOPERATIVE DIGITAL STUDIO IT-SUPPORTED COOPERATION FOR AEC STUDENTS

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### ABSTRACT

Teaching cooperation-related issues to AEC (Architecture, Engineering and Construction) students is a major stake nowadays. There are many reasons for that: construction projects become more and more complex and cooperation practices are evolving in both organizational and IT-based ways. It is notably for these reasons that the issue of IT is addressed in most of the AEC-oriented schools and universities. Traditionally IT is taught to support the tasks of each specific construction field (e.g. CAD for architects, simulation tools for static engineers etc.). The Digital Cooperative Studio, presented in this article, considers IT as a support to cooperation and especially its communication and coordination dimensions. Moreover, we describe here a living lab involving students, teachers and researchers. This strong link between research and teaching allows both the students to be “analysts” of their real project situations and the researchers to experiment their development in real project situations.

### KEYWORDS

Education, Architectural Design, Cooperation, IT-Services

### 1 INTRODUCTION

Construction projects become more and more complex, involve many actors, who are heterogeneous and work together for short-time periods. The professional practices are constantly evolving. The increasing number of actors involved in projects and the new needs of expertises are changing the cooperation practices in an organizational way. Moreover, these new practices are often based on the benefits of IT. New ways of working are enabled, such as representing the project or simulating its different aspects, but also supporting the cooperation practices through more transparent, described and managed flows of tasks and documents.

In the AEC educational curriculums, teamwork exists and students are often placed in collective situations, working in group on architectural/urban project design. These situations are close to the ones existing for example in architecture agencies, where some collaborators have to share tasks and documents to answer a client’s demand. This form of collective working is generally driven by hierarchy and procedures. But this type of group work is too limited and we think that students are not enough prepared to the collective and multi-disciplinary dimensions of construction projects. In such situations heterogeneous actors have to work together in unpredictable and changing environments. Furthermore, the participants of projects are often distant and they work at different time periods.

In this context, the use of IT tools is necessary to simply enable the collective work. Nowadays architecture and engineering schools students are familiar with numerous IT tools, useful to design, simulate and merely represent their architectural projects. But, once more, we notice that they are not aware of IT-based tools supporting cooperation between participants of a project (i.e. groupware tools).

For all these reasons we setup the Digital Cooperative Studio: an experiment of collective architectural design between distant teams of students. In this article we present firstly a brief state-of-the-art of other

digital studios. Then, we describe the 07-08 SDC aims, the organization of students' work and the IT-tools setup to enable cooperation activities.

## 2. VIRTUAL STUDIO OF ARCHITECTURAL DESIGN

### 2.1 ICT EDUCATION FOR AEC PROFESSIONALS: A STATE OF THE ART

For many years now, ICT has become a full-fledged field of education in the AEC-related curriculums. Following the professional practices changes regarding to ICT, schools and universities have integrated new courses to prepare the students to the use of these emerging tools. For example 2D CAD, largely used in practices nowadays, is also largely taught in the architecture and engineering schools (Hannu 2003).

An interesting topology of ICT in architectural design education has been established by (Sariyildiz et al. 1998). It distinguishes between three types of traditional tools: information processing tools, communication tool, and visualization tool during the creative design process. It includes also three types of emerging tools: knowledge integration tools, decision support tools and design tools. One can observe that the latest research innovations are also applied, often in experimental ways, in some AEC-related teaching fields: decision support tools and 4D simulation (Sampaio et al. 2007; Wang et al. 2007), architectural and morphological design tools (Prokop et al. 2005) or analog to digital conversion tools issues.

In parallel, the issue of cooperation is becoming more and more essential in the construction projects practices. In education many interesting cooperation-related activities also emerged. It is the case of the topics of knowledge integration, search and retrieval of information (e.g. educational), especially in cross-media ways (Fruchter 2007). The topic that interests us very much is the one of cooperation between members of a construction project. Moreover the research activities that we carry out are deeply anchored in the multi-disciplinary cooperation issues. The fundamental aspect of cooperation in collective projects has been defined by (Kvan 2000) and (Benali et al. 2002).

In the Virtual Design Studios, numerous aspects of cooperation have been described:

- The roles' distribution approach (Van Leeuwen et al. 2005),
- The scenarios to build project-organizations, to favour trust relationships, especially between geographically distant students (Cheng 1998; Donath et al. 1999),
- The cross-disciplinary approaches, placing an "AEC expert" (i.e. an architect, an engineer, a technicians...) in the need to cooperate with another "AEC expert" (Forgber et al. 1999; Fruchter et al. 2007).

Finally, the recent successes of the virtual worlds concept interested the teachers. Some experiments of co-design have been done in such virtual contexts, such as the eCAADe world (information storage & presentation, landmark in 3D/immersive Internet environments, experimentation on virtual collaboration and interaction) (Brown et al. 2001; Schnabel et al. 2001).

### 2.2 COOPERATIVE DIGITAL STUDIO (SDC): A FR/BE/LU INITIATIVE

In 2007-2008 the Digital Cooperative Studio was the result of an association between two academic institutions (Architecture School of Nancy & University of Liège) and three research laboratories from France (CRAI), Belgium (LuciD Group) and Luxembourg (Public Research Centre Henri Tudor). The educational curriculums are closer: a Master Degree in Nancy<sup>5</sup> and 2nd/3rd year of Architecture/Engineering studies in Liège<sup>6</sup>.

These partners are complementary by the study curriculum but also by the research projects that they carry out, both in the topics of Computer-Aided Architectural Design and of Assistance to Cooperative Activities in Construction.

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<sup>5</sup> <http://modelisation.nancy.archi.fr>

<sup>6</sup> <http://progours.ulg.ac.be/cocoon/en/programmes/AIICAR01.html>

### **2.3 PRINCIPAL AIMS**

For some years, at the Architecture School of Nancy, the initial objectives of our pedagogical experiments are to sensitize the students to the cooperation issues in Architecture. In 2004 our first studio put together French and Thai students to design an exposition of research works (Kubicki et al. 2004; Bignon et al. 2007). Since 2005, with the Architecture School of Versailles we have run several experiments of co-design with little groups of students, and using collaborative tools (Bignon 2007).

In these Digital Cooperative Studios (SDC) our principal aim is to put together students from different geographical origins and from different skills in shared design projects. The scenario of these projects is: working distantly (mixed teams from Liège and Nancy), involving different skills (curriculums are different in the different schools), in both synchronous and asynchronous ways.

This cooperative scenario is the ideal situation to sensitize the students to the use of cooperative IT-tools to communicate, to share tasks, to setup coordination... In one word: to co-design.

### **2.4 07/08 PROJECT**

The 07-08 cooperative studio involved 29 students from Nancy and Liège. The architectural project consisted in designing a "House of Environment" (3000 m<sup>2</sup>), comprising a conference centre, a library and a cafeteria. The site was in Nancy, France.

The environmental issue was chosen by the pedagogical team for many reasons. Firstly, it is a contemporary topic, emerging from current considerations (e.g. on climate changes, energy savings etc.), which is attractive for future architects and engineers. Secondly, this issue was interesting in stimulating cooperation between students. In fact sustainability in building should only be raised by collaborative teams of experts, bringing their forces together to address its numerous dimensions. Finally, in their master's curriculums, the students acquired competencies in diverse computer simulations. It was interesting to re-use it to perform sustainability assessments on the projects: 3D modeling, natural/artificial light evaluation and energy efficiency.

## **3. SDC ORGANIZATION**

### **3.1 TIME MANAGEMENT**

Three essential steps had marked out this Digital Studio:

- The kick-off meeting in Nancy allowed all the students to meet, to visit the project's site and to constitute the working teams. This "Kick-off one-day workshop" allowed interpersonal relationships to become established. This way of working has been demonstrated in the past year and applied by other pedagogical teams (Elger et al. 2001).
- The intermediate projects' presentation in Web conference was the moment to point out the critical options on the projects and to reinforce the roles of each student in the projects.
- The final presentation in Liège, where all the four projects were presented by the students and evaluated by the teaching team. This presentation consisted of both an architectural/technical/environmental description of the projects and a critical analysis of the cooperative dimension of the studio.

### **3.2 TEAMS**

The teams were composed of 6-7 students from Nancy and Liège. The duration of the studio was quite limited in time (3 months from October to December).

The teaching team has defined 7 particular roles that the students had to take personally: architectural composition, interior spaces design, environmental quality responsibility, natural and artificial enlightening, structural engineering, special engineering techniques, and energy management.

Based on our previous virtual studio's experiences we thought that giving each student a particular responsibility was essential to stimulate them. It was all the most important since 1) the duration was limited and 2) the teams was quite big.

### 3.3 THEORETICAL COURSES

The pedagogical inputs consisted both in a supervision of the architectural projects' design and in a set of theoretical courses.

Weekly supervision in Nancy and Liège consisted in guiding the students in their projects. Architectural and technical options were guided by the teaching team in order to choose forms (morphology) and techniques favouring the involvement of the different roles and the necessity of exchanging information.

Theoretical courses was taught both in Nancy and Liège through Web conferences. They addressed some topics related to cooperation in design activities and were strongly inspired from theoretical research results. The metamodel of the cooperation context that we have developed (Kubicki et al. 2005) is particularly adapted to introduce to the students the essential concepts related to cooperation: actors (e.g. organizations of actors), activity (e.g. tasks coordination, project management), documents (and especially the ones supporting coordination) and finally the assistance tools (taxonomy of tools supporting cooperation).

The notions of actor organizations and task coordination are especially focused in these courses. In addition we insist on examples applied to the design and construction collective activities in AEC. We also taught issues related to object sharing. The standardization of building's object description was introduced through the concepts of digital mock-up and the description of the IFC format.

### 3.4 COOPERATION PROCESS

In 2007-2008, SDC had taken place from October to December, during 13 weeks. In order to perform the work and to realize the project, a cooperative process (Figure 1) was defined with the students. This exercise was based on the main concepts related to cooperative projects taught in the theoretical courses.

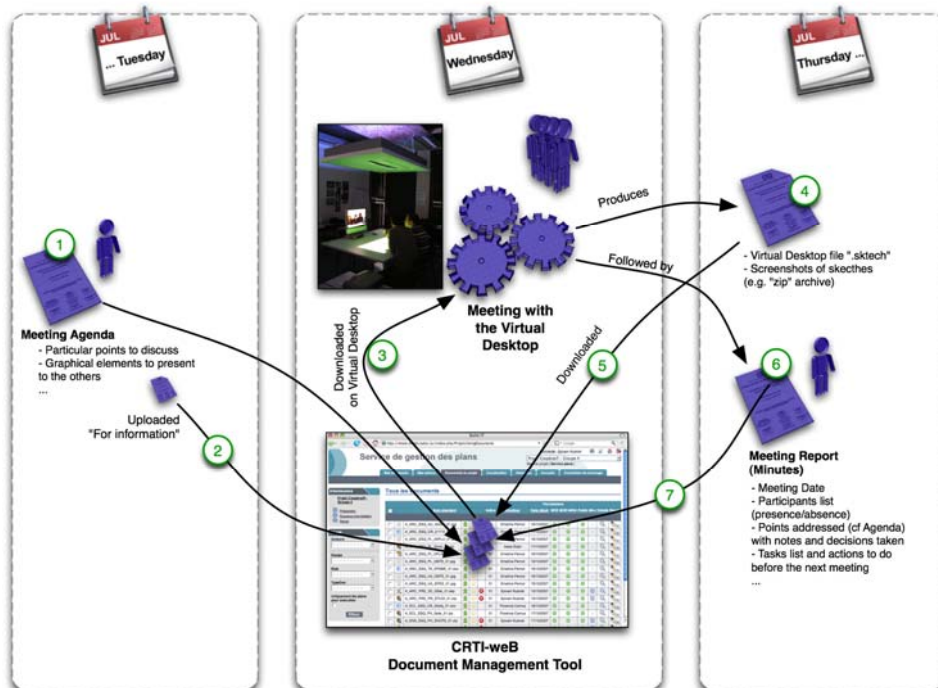


Figure 1: The cooperative process in SDC 07-08

The main idea of this standardized process was to sensitize the students to the necessary management of exchanges and interactions that they had to setup in order to facilitate cooperation and to enable coordination of their tasks. At this step they had to decide who could handle the coordinator's role in each group. We will discuss below in part 4 the tools represented in the Figure 1.

The cooperation process could be described in three weekly stages. The central stage was the Wednesday synchronous team meeting. Each part of the teams virtually meets at the same time in Nancy and in Liège. This coordination meeting was the essential stage enabling to share ideas, to debate and to take decisions.

Prior to this meeting (each Tuesday) the meeting preparation task consisted in preparing the documents to be discussed. It was also demanded to prepare a meeting agenda ensuring to structure and optimize the meeting time.

And after the meeting a task of meeting report consisted in writing what had been decided. This essential document was the “written trace” of the exchanges and of the taken decisions. This meeting report had to be approved by all the members of the team.

#### 4. A SET OF INNOVATIVE COOPERATION-SUPPORT TECHNOLOGIES

More than a Master course, SDC is also a real “living lab” to experiment IT-services resulting from our research projects. We introduced strong relationships between the work process (Figure 1) and the tools made available to the students in order to facilitate their cooperative distant work. The use of a document management system (§4.1) and of a Virtual Desktop for sketch sharing (§4.2) led the students to be sensitized to the benefits of IT to support their cooperative practices.

##### 4.1 CRTI-WEB: A DOCUMENT MANAGEMENT SYSTEM

The document exchange server “CRTI-weB” is a Web platform<sup>7</sup> (Figure 2) developed by the Public Research Centre Henri Tudor in Luxembourg. It consists of a shared project space, available for all the participants of a project from every computer connected to the Internet. It allows the project’s members to upload the documents that they produce in order to design the architectural project, and to share them with the others. The aim is to centralize the documents and to trace their updates and modifications. Moreover it enables also to notify the users when a document is available, and to assign task (requests), such as validation tasks or reaction demands. The reaction functionality is a real “discussion forum” between project members about a specific document.

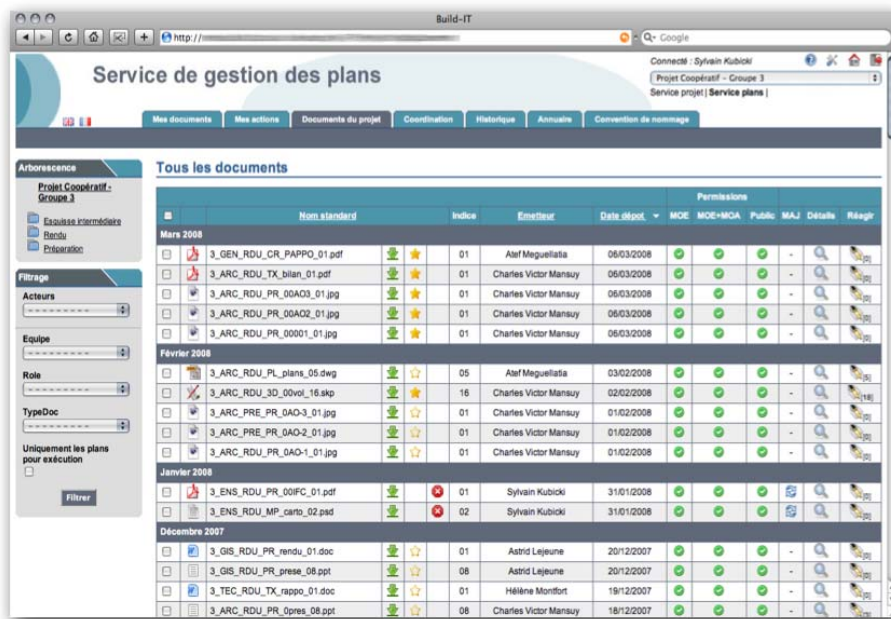


Figure 2: CRTI-weB document management server

<sup>7</sup> A demo access is available at <http://demoged.builtit.tudor.lu> (login: “demo”, password: “demo”)

#### 4.2 SKETSHA: A VIRTUAL SKETCHING TOOL

The Virtual Desktop (Figure 3) is a tool developed by the University of Liège, in Belgium (LuciD Group laboratory<sup>8</sup>). During a distant project meeting, it allows its users to draw and sketch on a shared virtual workspace.

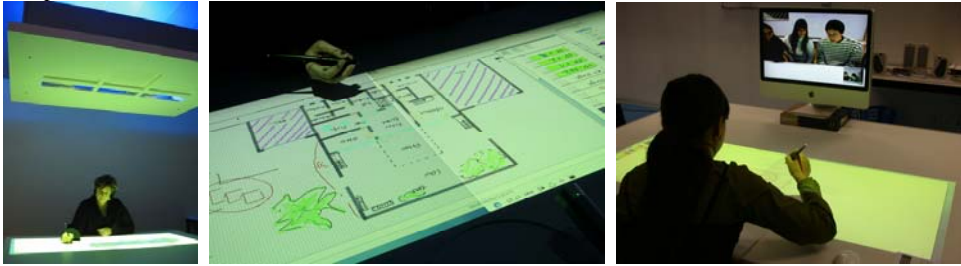


Figure 3: The Virtual Desktop and its software, Sketsha

This tool comprises both a software part and a hardware part. The desk itself is composed of a large tactile table with which the user interacts with a stylus. Two video projectors display a Mac OS X computer environment.

The software “Sketsha” completes this hardware. It allows the users to draw on the table with the stylus, manage sketch layers and the imported reference images. Sketsha displays the sketch on the two distant screens and manage coherence and changes in real time. The users can then co-edit the project while he discusses in real-time with the Web conference system (iChat).

### 5. DISCUSSION

#### 5.1 STUDENTS' FEEDBACK

The students' feedback was largely favourable to the pedagogical approach in this Digital Cooperative Studio. At the end of the semester the overall student's belief was that traditional curriculums do not prepare them very well to the cooperative dimension of construction projects. In this way, the theoretical courses associated to the real design project situation were an interesting living lab, where “theories could be applied to real projects”. However students noticed also that too theoretical courses were hard to understand/apply. They asked for applied examples to communicate organizational or coordination-related theories.

The unbalanced work-planning between Liège and Nancy students had been also noticed. This has led to difficulties related to different engagement levels in the projects. This problem intensified another one related to the roles' distributions. In fact the engineers sometimes felt confined to a “verifier” role in charge of validating design choices. It was probably due to the unbalanced work-plannings, to a certain lack of teaching instructions, but also to the communication difficulties (due to the geographical distance between students).

Concerning the tools, the feedback had been also globally positive. The use of innovative tools motivate the students. We think that the feeling of participating to the tools' specification/development/improvement is important to stimulate their use. Remarks concerning tools-related feedbacks are developed in parts 5.3 and 5.4.

#### 5.2 PEDAGOGICAL RESULTS

The short duration of the studio (3 months) has been an obstacle for the students in delivering a well-detailed proposition of their architectural projects. Nevertheless we observed that if the overall projects were not well-defined, the role's allocation allowed the students to detail and improve some specific aspects related to their role.

Thus, for each project (Figure 4), a structural study has been performed, natural enlightening simulation guided the facades' design, or the energy loss evaluation oriented the choice and assembly of materials.

<sup>8</sup> <http://www.arch.ulg.ac.be/Lucid>





Figure 4: The four architectural projects designed

An interesting remark is that these roles have been addressed by the students as complementary. It means that they understood that one role had to receive the work of another one, to validate it and to send back a validation or not, in a sequential process. The teaching team tried during the semester to change this “collaborative” way of working and to favour a more “cooperative” way of working. The results were interesting. In a team in particular an iterative attempt/error/redesign scenario has been setup and guided to very interesting results. In this approach, the technical roles were not limited to a verification role, but they had a real place in the design process, e.g. suggesting solutions and compromises. Figure 5 (realized by the students themselves) presents this cooperative process applied to the stages of the façade design.

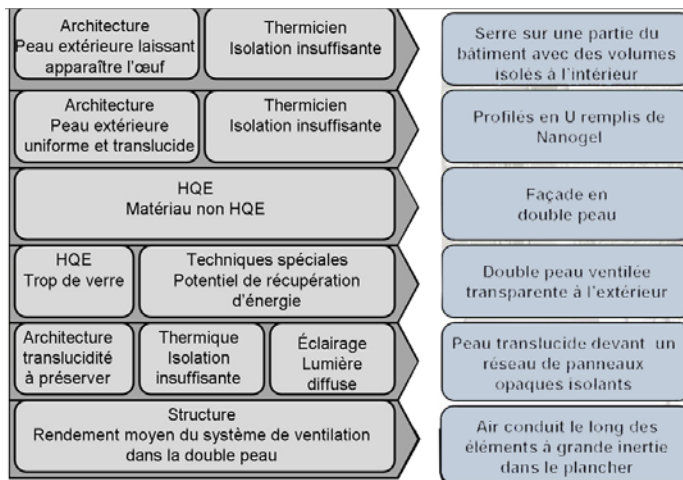


Figure 5: Cooperative process, as applied by one group on the facade design choices

### 5.3 TOOLS EXPERIMENT FEEDBACK

The use of the research-issued tools led us also to assess on their use in real project's cases. The Virtual Desktop designed as an easy-to-use, sketch-based tool has proved its ability in sketching in a natural way (horizontal table). Moreover its cooperative sketch display was useful in sharing ideas and in co-

sketching (2 hands on the same sketch). The students noticed the need to initially understand how it worked, and after that the use was easy and efficient.

The document management server was also assessed during the SDC. The critical point in its use was the definition and implementation of a standard naming for the documents. This point was quite hard to understand for students who were not familiar with the difficulties related to document exchanges between heterogeneous groups of actors. But we can see in the Figure 4 that it was not a problem in the use of the tool. It had constantly been increasing from October to December.

Figure 6 shows the increasing number of documents uploaded to the server. This number was quite homogeneous between the four groups of students.

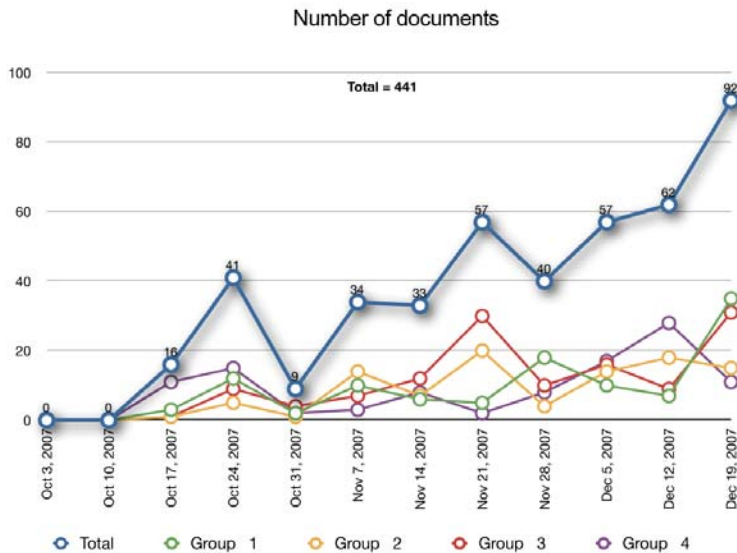


Figure 6: Number of documents uploaded on CRTI-weB server

Figure 7 shows the number of reactions sent by the students about the documents. In this case we can notice that the use of this functionality is variable between the groups. In fact, some groups had used the tool to communicate and other groups used instead other external communication tools (as MSN messenger).

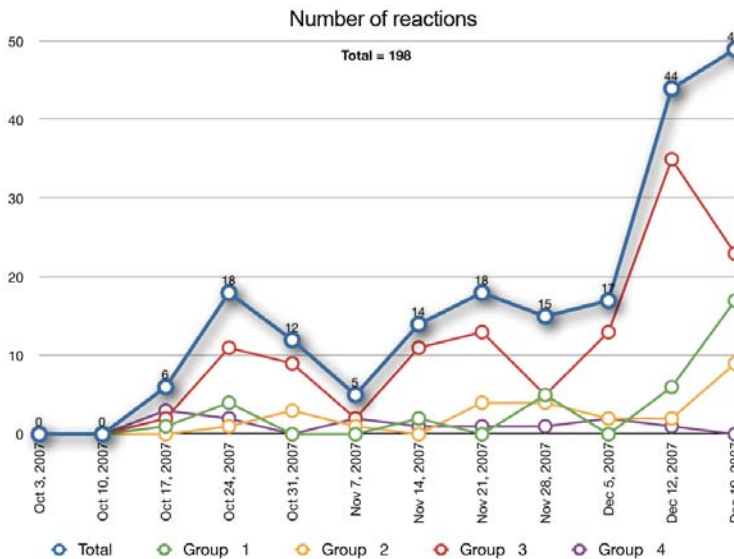




Figure 7: Number of reactions about the documents on CRTI-weB server

#### 5.4 TOOLS IMPROVEMENT IDEAS

During the studio and in the final enquiries we were interested in the feedback about the use of the experimental tools by the students. The difficulties have been mentioned above. But many improvement ideas also emerged. So far as we could, we have tried to take the remarks into account in real time, and to improve and update the tools during the semester. A new release of Sketsha delivered new functionalities to manipulate the sketches (move, rotate...). The CRTI-weB document server was also updated many times, especially to repair the bugs discovered by the students.

In terms of improvement, we noticed the idea of integrating a discussion forum or a chat service in the CRTI-weB server. The notification function was also criticized and should have to be improved through customization options. Some ideas related to visualization of the documents were also formulated, such as preview of pdf documents, or ideas related to the documents' list Human Computer Interface.

Another interesting idea has emerged. It consists in integrating the two tools to offer new possibilities such as importing a document directly from the CRTI-weB server to Sketsha, or saving a sketch to the server. This interesting idea will probably be envisaged in future research cooperation.

#### 6. CONCLUSION

Projects and experiments of collective design are essential in AEC curriculums. Future practitioners have to be sensitized during their studies to the cooperation mechanisms, methods and tools facilitating their future practice.

One challenge for pedagogical teams is to transmit the theoretical concepts related to cooperation and coordination to the students who are often focused on their project design exercises. In SDC we privilege a mixed approach both conceptual and applied. Theoretical courses coming from research developments are immediately applied in the project teams through a standardized basic process (Figure 1) built with the students themselves. The cooperation was also stimulated by the subject itself: a house of environment. The project had to be designed according to sustainable development criteria and each student wore an organizational role related to a specific criterion.

Beyond the organizational aspects of cooperation we also have to make students aware of the emerging technologies supporting cooperation. A strong link existing between our research projects and the pedagogical studio allows students to experiment innovative IT tools (i.e. groupware). These "living lab" projects are interesting both for the students, future users of cooperation-support tools, and for the researchers, to get feedback from the use of their experimental tools.

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