COLLABORATIVE DESIGN IN ARCHITECTURE: A TEACHING EXPERIENCE

Regina C. Ruschel
Department of Architecture and Construction
School of Civil Engineering, Architecture and Urban Design, University of Campinas
Brazil
regina@fec.unicamp.br

Gabriela Celani
Department of Architecture and Construction
School of Civil Engineering, Architecture and Urban Design, University of Campinas
Brazil
celani@fec.unicamp.br

Autímio Batista Guimarães Júnior
Graduate Program in Civil Engineering,
School of Civil Engineering, Architecture and Urban Design, University of Campinas
Brazil
autimio@gmail.com

Thales Augusto F. Righi
Graduate Program in Civil Engineering,
School of Civil Engineering, Architecture and Urban Design, University of Campinas
Brazil
thales@gmail.com

Abstract
The present paper describes an undergraduate class called "Collaborative and Integrated Design". The subject has just been introduced in the Architecture and Urban Design course at the State University of Campinas, as the last in a series of 10 studios, just before the final design project, which is developed individually in the 11th and 12th semesters. The objective of the class is the development of an integrated architectural and engineering design project by a distributed team, with the support of Information and Communication Technology and with an emphasis on the use of Computer Aided Architectural Design (CAAD). Civil Engineering Graduate students acted as distant team members and consultants for each of the four undergraduate student groups. The class program will be presented. The use of digital resources to support in-class and online collaboration, such as the use of an interactive whiteboard, broadcasting of class assistance, and a collaborative environment, will be detailed. The observed collaboration will be analyzed and student acceptance of the teaching and design approaches will be discussed. Lessons learned considering design management in AEC will also be discussed.

Keywords: collaborative design, design education, computer aided architectural design.

INTRODUCTION

The course of Architecture and Urban Design at the University of Campinas is young, initiated in 1999. Its pedagogic project aims the architect of the future, where productivity and creativity must be applied for the understanding of the interrelationship between man and environment. It is considered that the quality of the preparation of an architect is directly associated to design education. Therefore, building design was chosen to be the course emphasis associated to design methodology, computer aided architectural design, environmental comfort and sustainability.

In the exercise of design there is the need to embrace complexity with creativity and effective idea communication. The teaching of these abilities requires an environment where design reasoning can be developed with logic, methodology and communication techniques (Rowe, 1992; Mitchell, 1992). Design education must include theory and methods for the creative process and Computer Aided Architectural Design, multimedia, programming, evaluation, simulation and optimization can be seen as important tools in such context.

The course of Architectural and Urban Design at UNICAMP intends to aggregate such a teaching environment through a sequence of studios, design exercises and laboratory support. This study discusses an action research in order to improve educational goals of a collaborative design class in an undergraduate architectural degree. Being the last in a series of 10 studios, which precedes the students´ final design project. The objective of the class is the development of an integrated architectural and engineering design project by a distributed team, with the support of Information and Communication Technology.

STUDIOS AT THE ARCHITECTURAL AND URBAN DESIGN COURSE

The Architecture and Urban Design course at UNICAMP emphasizes design. Building design must be based on technical, artistic and scientific-theoretical knowledge. This design process needs creative stimulus as well as the development of communication skills. Skills are practice though a structured program of four applied computing classes, four drafting and design classes and ten architectural design and theory classes (Table 1). During the last year (6^{th}) of the course each student must develop an individual design project.

Table 1: *Distribution of design & theory, computing and drawing classes*

YEAR	SEMESTRE	THEORY&DESIGN	APPLIED COMPUTING	DRAWING
1	1	AP111	AU301	AP211
1	2	AP112	AU302	AU212
2	1	AU113	AU303	AP213
2	2	AU114	AP312	AP115
3	1	AU115		
3	2	AU116		
4	1	AU117		
4	2	AU118		
5	1	AU119		
5	2	AU120		

The format of design classes is a combination of design studio with seminars. Design classes evolve from a general composition class on the first semester to a complex design project on the sixth year. The objectives of the ten studio classes that are taught before the final project are listed below:

- AP111 General composition, space, volume, colors, textures, light and rhythm.
- AP112 Design method, definition of the parti, analogies, typologies, definition of construction processes and pre-fabrication.
- AU113 Fundamental issues in architectural design – functional, psychological, social, economic, cultural, environmental, aesthetic, ecologic and legal. Definition of the design program.
- AU114 Social housing design. Design of collective, open-air spaces.
- AU115 Architectural design and thermal comfort.
- AU116 Architectural design, natural lighting and energy conservation.
- AU117 Architectural design and acoustics.
- AU118 Functionally complex architectural programs.
- AU119 Vertical buildings.
- AU120 Collaborative design: integration and collaboration in the design process.

Several of the drawing classes have artistic references. Free hand drawing is taught to practice memory and spontaneous communication skills in the first drawing class (AP211). The second drawing class (AU212) presents technical drafting in traditional sense including drafting norms, which are practiced for complete building design documentation. To attain the 3D abilities of volumetric visualization and 2D representation, orthographic projection of objects, typical to engineering graphics, is also practiced. The third drawing class (AP213) is a mix of design and drafting, where form and volume compositions are developed. The last drawing class (AP115) belongs to industrial design, where product design is taught with communication skills appropriate for production line processes.

Each of the applied computing classes have specific goals, related to problem analysis, and solution finding in design exercises. We agree with Martens, Koutamanis and Brown (2007, p.524) on the need of future architects to acquire skills on a wide range of application from image-making and building information modeling to digital fabrication. Theses classes are taught during the two first years of the course, to support the design studios (Table 1) :

- AU301 Introduction to computation (spreadsheets, text editors, image editors and basic web design)
- AU302 CAD drafting and 3D modeling.
- AU303 CAD in the creative process.
- AP314 Animation.

In the first computing discipline communication programs are introduced as well as efficient operation in the World Wide Web. Such programs include image creators and editors, HTML editors and advanced presentation tolls. Theses tolls offer means for graphic expression as first communication of ideas and solution. The initial design class (AP111) develops in parallel the theory of form, color, texture and aesthetics for architectural design. In sequence, the second and third design class (AP112 & AU113) have connection with the computing classes of CAD where focuses is given to 3D modeling and programming in order to obtain varied design solution to similar problems. To expand graphic expression *repertoire* the last applied computing class explores multimedia tools and animation.

In order to support the studios and classes above, as well as research carried out by professors and students, providing an adequate environment for practice and experimentation, the school has four laboratories: LAMPA (CAAD research laboratory), LACAF (environmental comfort laboratory), LMM (traditional model shop) and LAPAC (rapid prototyping laboratory).

However, in the third and fourth year design classes develop as traditional studios where a disjunction between design studio and computer lab persists. In such design classes student production is followed upon presentation drawings, rendering and scaled models. In order to overcome such scenario and implement a more immersive digital design teaching as suggested by Vincent (2007), the class of Collaborative Design is given in a studio which is a mix of laboratory and traditional room setting, where students present and have the opportunity to discuss production over the original digital model, images or video of project site or reference projects. The first offering of Collaborative Design studio (AU120), taught at the 10th semester of the course will be presented in the following sections.

THE CLASS OF COLLABORATIVE AND INTEGRATE DESIGN

Program and intended collaboration

Collaboration is thought as a joint problem solving, where as pointed out by Kvan (2000, p. 410) "it means working with others with shared goals for which the team attempts to find solutions that are satisfying to all concerned." Therefore, two groups of students were involved in a design exercise in the second semester of 2007: the undergraduate class of Collaborative and Integrated Design (AU120) of the course of Architecture and Urban Design and the graduate class of Collaborative Design (IC039) of the Graduate Program in Civil Engineering, both from the State University of Campinas. The undergraduate class involved approximately 25 students and the graduate class 12 students. The design exercise was of a **sustainable tourist complex** as proposed by the 3rd Latin American BIENAL of Architecture Students which occurred during the XXII Latin American Conference of Architecture Schools and Colleges (http://www.arqchile.cl/clefa.htm). Students should identify an area declared as national patrimony with tourist potential and develop a complete urban-architectural project that allowed sustainable tourism.

Four design teams were composed of undergraduate and graduate students of the involved classes, that is, AU120 and IC039. Each team should develop its own project. Each team had at least one civil engineer. The design process should follow four stages and for each stage specific products were developed allowing student evaluation. The first stage was of survey, where project location should be defined, reference projects selected and theoretical foundation presented. The second stage involved the development of the architectural program and respective viability analysis. The third stage was of the conceptual design. Finally in the fourth stage the preliminary project should be developed.

We agree with Hamid (2007, p. 713) that collaboration is a social phenomenon, where the social interaction is dynamic and involves individual that reflect ideals such as leadership, shared understanding and conflict resolution. Therefore, we proposed the collaboration scheme presented in Figure 1, where the iteration process between design phases for product refinement is present and involved by planning and evaluation. The collaboration between graduate and undergraduate students could be of various types: information provision, advisement, management or integrated development and could occur in planning of design phase, during individual work and in evaluation process. Undergraduate students were mainly

evaluated by product development, also considering the collaborative attitude. Graduate students were evaluated for the collaborative work and the analysis of the collaborative process.

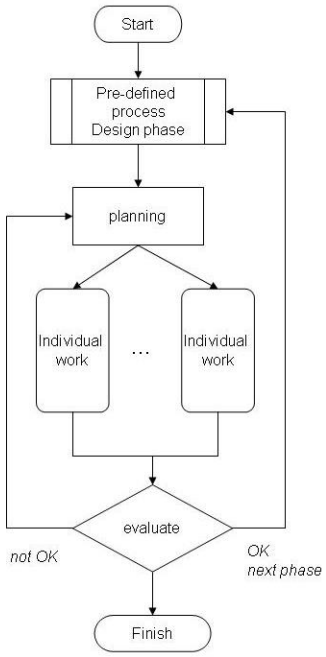

Figure 1: *Collaboration scheme proposed for the design class*

Graduate and undergraduate students were both from UNICAMP, however their classes were in a different period: during the day and at night respectively. Therefore, team communication; document sharing and collaboration should occur through the collaborative environment, online meetings (using chat or Skype) and eventual face-to-face meetings. The graduate students could watch undergraduate project presentations of each design stage by means of webcasting. Presentations were filmed and broadcasted in real-time.

Tools used

Beyond common CAAD tools (CAD, rendering, animation, image editors, electronic sheets …) two collaborative tools were used: one asynchronous and the other synchronous. The asynchronous collaborative tool was a Web-base Project Management Systems (WPMS). The synchronous tool was an interactive whiteboard used in studio design advisement. These tools will be presented in the sequence.

Web-base Project Management Systems (WPMS) are electronic systems for project management conducted in an extranet (a private net which uses internet protocols for information communication) (Nitithamyong; Skibniewski, 2004). WPMS are systems with restricted access to a project team, where project data is deposited in a central server. The WEB browser is used in order to exchange data, as drawing, documents, images and so on, among team members. The WPMS used in this collaborative design class was the Construmanager (http://www.e-construmarket.com.br/aec/colaboracao/), which is of the Application Service Provider (APS) type developed in Brazil by E-construmarket.

The Construmanager collaborative environment offers resources such as: central repository (named Files or Content), agenda management, meeting minutes, electronic mail, process and activity management. The functionalities associated to the central repository are:

Upload/Dowload (transfer of files between client and server), Update (file upload with version control) ;Check-in/Check-out (file edition signaling); Exclude/Move/Copy (file manipulation in the server directory); Approve/Deny (coordination tool for file approval); Title/Edit (tools for file identification); Markup (allows file graphic commenting); Visualize (DWG or image visualization with generic tool) and Discussion (allows file text commenting).

Figure 2 presents a screen of the WPMS Construmanager where on the left directory folders is shown, by its side the pull down menu including repository functionalities is presented and to the right the visualization of a graphically commented imaged is opened.

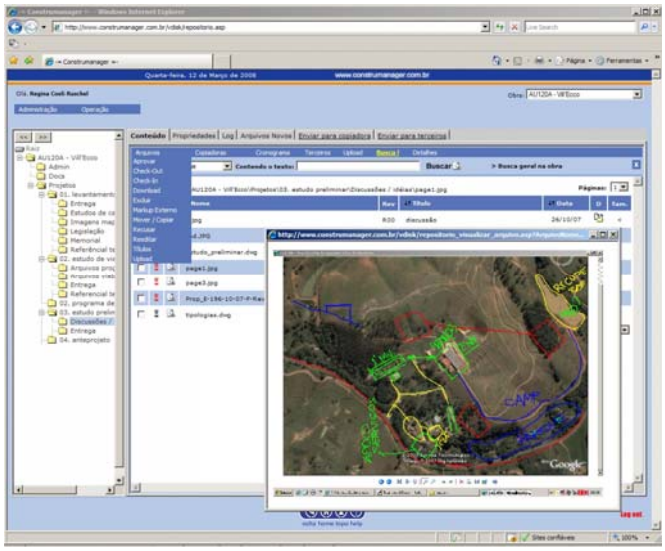

Figure2: *The WPMS Construmanager*

The interactive whiteboard was used for synchronous collaboration among undergraduate student members of the teams in the studio, especially during critic sessions. Figure 3 shows a typical studio situation in which a team was showing their design to the studio instructors. The advantages of using the whiteboard were twofold:

1. It made it possible to comfortably present and discuss evolving design projects with groups typically formed by 8 people (6 students and 2 instructors), using digital information, in a comfortable way (as opposed to using printed drawings or a small computer screen).
2. The interactive whiteboard software allowed drawing and recording red-marks onto the drawings presented. The images with such red-marks and comments were then posted in the collaborative environment, so that the graduate members of each team would see the instructors' suggestions and help students implement them (Figure 2).

Figure *4* shows a typical example of redmarks made to a work-in-progress drawing design on the interective whitebooard during a crit session. Images like this were posted on the online interactive environments to keep a memory of the evolution of the projects.

Figure 3: *Use of the interactive whiteboard during a critic session*

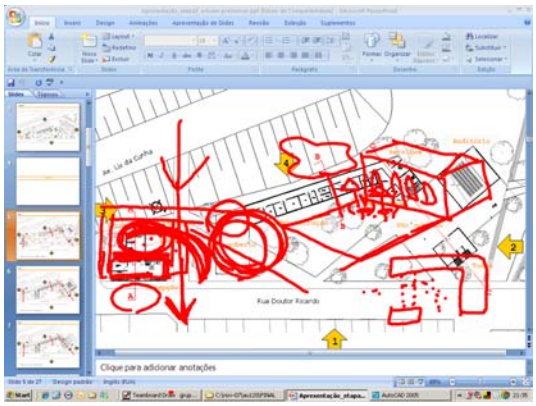

Figure 4: *Example of redmarked image during a crit session*

Students work

All the four teams were able to develop projects that included architectural layouts, structural and HVAC schemes, economic viability studies, and had a good relationship with the historical sites where they were inserted.

Figure 5 shows some images of the projects presented at the final review. The HVAC schemes, fabrication details and structural 3D models presented were well beyond the level of detail that is usually presented in the other studios in the curriculum. They were the result of the participation of graduate students as design consultants, but also of the effective collaboration with them.

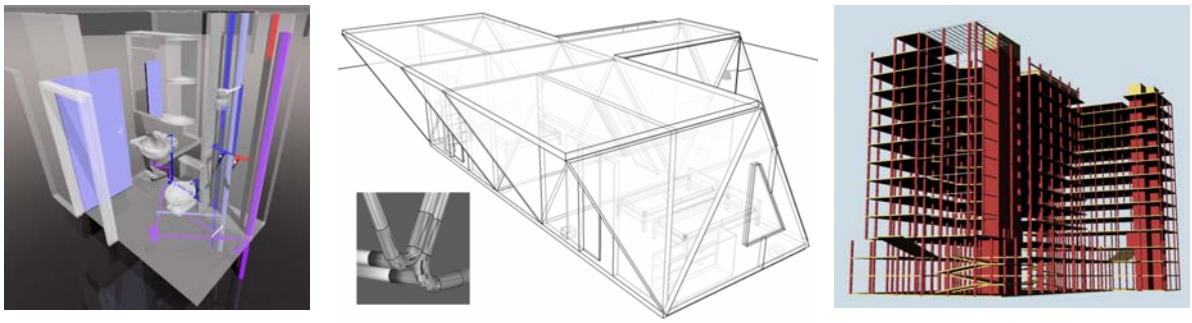

Figure 5: *Some aspects of the final projects:HVAC scheme, fabrication details and structural 3D model*

EXPERIENCE ANALYSIS

A pool was applied at the end of the experience in order to obtain student opinion over the collaboration process and used tools. The first question of the poll enquired which were the collaborative environment resources mostly used among: agenda, email, file repository, meeting minutes and process/activity management. Multiple answers were allowed. It was verified that all the resources were used by graduate students and that three most used were the file repository, email and meeting minutes. Among undergraduate students, only three resources were used coinciding with the three resources mostly used by the first group; however in different intensity (Figure 6). It can be observed that one group took more advantage of the tool than the other.

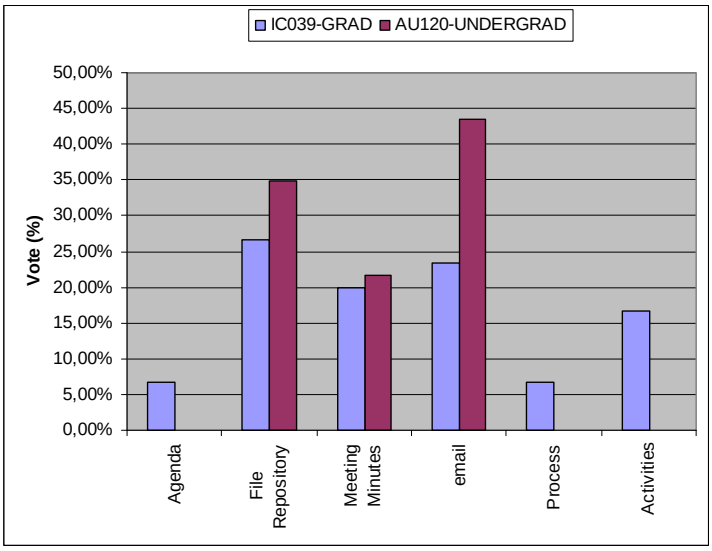

Figure 6: *Resources used in the collaborative environment Construmanager*

The second question of the poll enquired which functionalities of the file repository were mostly used among: upload/update/download, approve/reject, check-in/check-out, move/copy/exclude and title/reedit. Multiple answers were also allowed. It can be observed a very distributed use of these functionalities among graduate students, being the upload and download the ones mostly used by both groups (Figure 7). However, functionalities such as update and markup, which empowers digital collaboration, were poorly used.

The third question of the poll enquired about the type of collaboration which had occurred among: team development, task distribution, information sharing and/or advisement. Two answers were allowed. The graduate students declared to have collaborated mostly providing information or advising. The undergraduate students indicated that they also collaborated through information sharing but also by task division (Figure). Unfortunately, team development was not declared.

The fourth question of the poll enquired how collaboration had occurred. Multiple answers where allowed. The three main formats of collaboration declared by graduate students were: file sharing through the collaborative environment, through Google environment and in present meetings. A totally different scenario was presented by the undergraduate students, who declare collaboration mainly by email file transfer, present meetings and online meeting (Figure 9). We can observe that the graduate students were using digital resources more appropriate to the experience than the undergraduate students. Undergraduate students were

not able to embrace the new design experience being proposed due to previous studios teaching models.

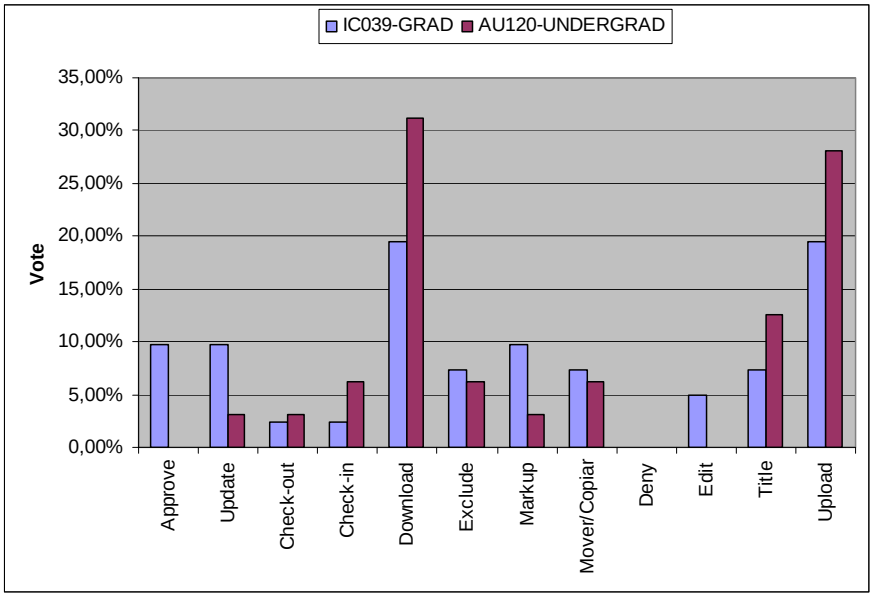

Figure 7: *The use of File Repository functionalities of the environment Construmanager*

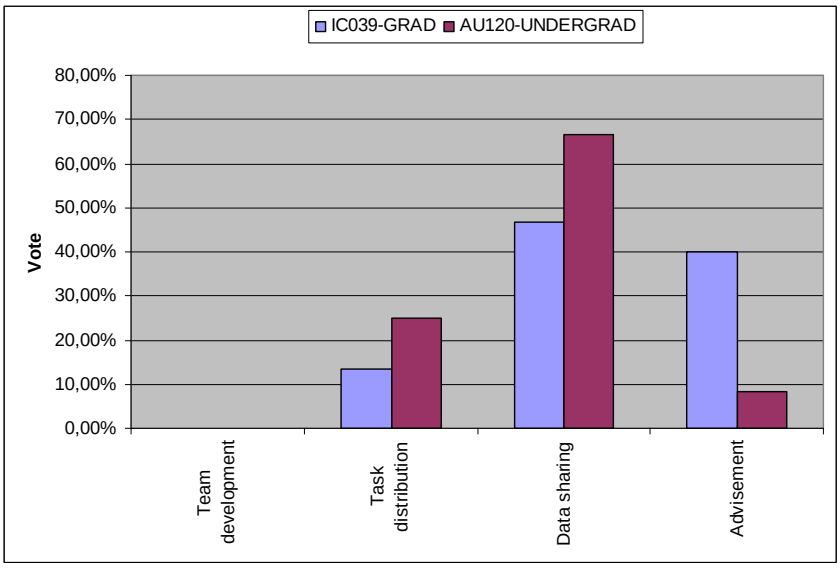

Figure 8: *Types of collaboration*

The final poll question enquired which design staged occurred more digital collaboration. Here the answer should be unique. Both group declared that the highest level of collaboration occurred in the last stage of design. It was also observed a non linearity in collaboration including discontinuation (Figure).

Also the logs on the collaborative environment were analyzed. In this second type of evaluation we searched to confirm opinions on collaboration over effective data sharing though the environment. In this text we will present results only on types of files used in the design exercise and shared by means of the collaborative environment. It can be observed a coherent use and sharing of files related to design stages (Figure 11).

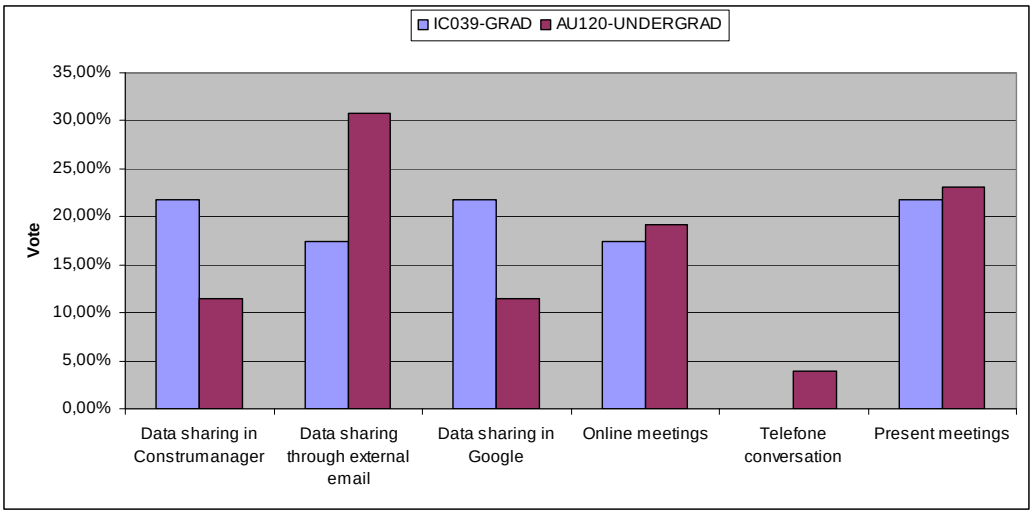

Figure 9: *Collaboration format*

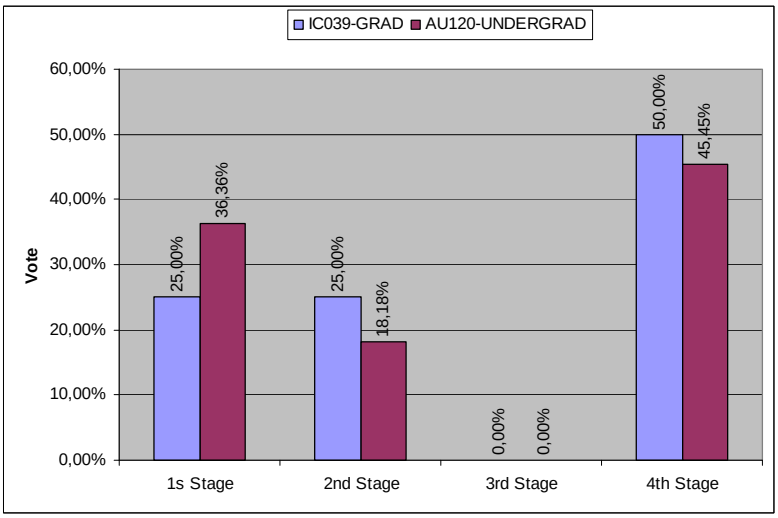

Figure 10: *Collaboration in design stages*

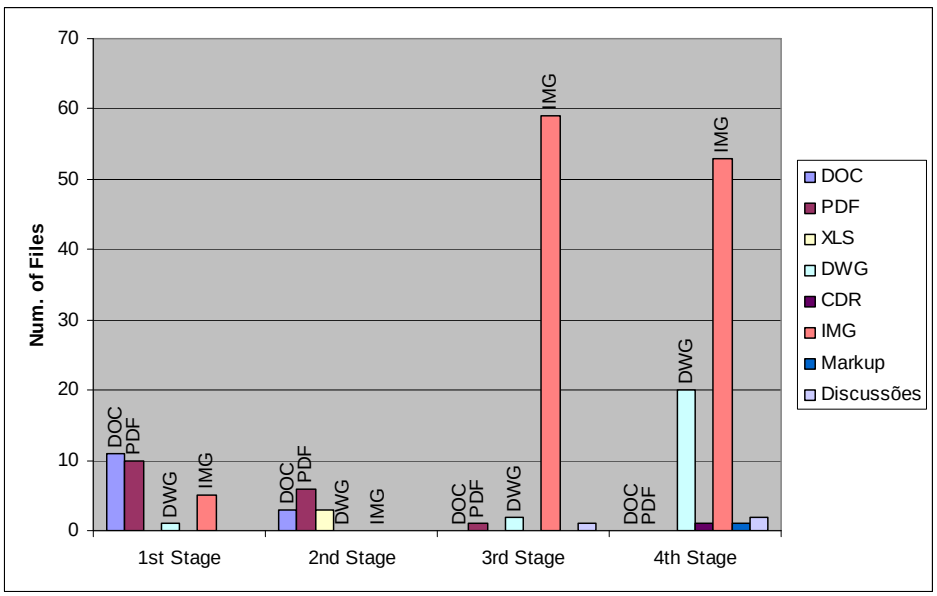

Figure 11: *Types of files deposited in the collaboration environment Construmanager*

LESSONS LEARNED

This study discusses an action research in order to improve educational goals of a collaborative design class in an undergraduate architectural degree, where the offering of the class here presented represents the first cycle of the research in progress. The objective of the class was the development of an integrated architectural and engineering design project by a distributed team, with the support of Information and Communication Technology and with an emphasis on the use of CAAD.

The positive aspects of this experience were student work, which were well beyond the level of detail that is usually presented in the other studios in the curriculum. Such products were the result of the participation of graduate students as design consultants and also of the effective collaboration between undergraduate students. Also interactive whiteboard used for synchronous collaboration among undergraduate in the studio, especially during critic sessions were very well accepted. It made it possible to comfortably present and discuss evolving design projects with groups typically formed by 8 people, using digital information in a dynamic and flexible way. The interactive whiteboard software allowed drawing and recording red-marks onto the drawings presented. These images were then posted in the collaborative environment, so that extended team could see the instructors' suggestions and help students implement them.

However we noticed in this teaching experience that an underlying architectural design approach for CAAD and novel collaborative design is needed. Students were more comfortable with 2D drawing than 3D geometric models as tools in the design process. Students did not apply prior teaching in computational design to test and/or create alternative solutions. Overall resources of the collaborative environment were poorly used. Also the collaboration between the two classes did not happen as imagined. The dominant mode for using computers in design as a combination of manually driven design decisions and formal responsive computer application, presented by Terzidis (2007, p.220-221), was observed.

Actions must be taken in order to improve class exploitation in future offerings. One idea is to invest strongly on guided architectural design approach for CAAD as presented by Duarte (2007) and Vincent (2007). Complementary mechanisms to encourage digital novel collaborative posture should be applied. As pointed out by Hamid (2007) the collaborative process is context-dependet. Therefore, we believe that the design exercise proposed encouraged traditional collaborative process and design. A more integrated and interdependent design exercise will be tested in the next offering of this class, therefore the next cycle of this action research.

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