COLLABORATIVE DESIGN AS AN EXPERIMENTAL MULTIDISCIPLINARY APPROACH TO DEVELOP COMPUTER AIDED ARCHITECTURAL DESIGN (CAAD) COURSES

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Abstract. This study demonstrates an overview of the state of teaching Computer Aided Architectural Design (CAAD) in the Department of Architecture, Misr Academy for Engineering and Technology (MET). This course is basically designed to enable students to explore new ways of design using Computer Aided Architectural Design software. In hypothetical valuation analysis, the study examines the necessity of combining ICT with architectural courses' teaching in a collaborative design manner. In this sense, it tackles an experimental multidisciplinary approach to develop CAAD courses. It focuses on the innovation of the course by the introduction of ICT both in the contents of the course and as a means of education. To attain its goals stated above, the paper discusses the differences between teaching CAAD by using standard software and teaching the principles of CAAD. It distinguishes four-interdisciplinary system of application for collaborative design in education: social systems, professional systems, educational systems, and innovative systems. This exploration is seldom backed up from a design methodological viewpoint. The conclusion shows how the developed CAAD course, when taught in combination with ICT and collaborative design approaches may result in favorable learning outcomes.

1. Introduction

The increasing speed of technological improvements outpaced many planning and design-related issues. Architectural education has been recently accepting digital design tools and technologies as a feature integrated in design processes and methodologies. In the meantime, achievement of accreditation for architectural education in Egyptian universities necessitates the quality of courses' teaching and learning to be developed in terms of

resources allocation, evaluation and assessment processes, and the planning approach to demonstrate capacity and respond to future challenges and opportunities (Sheta, 2006). In advanced teaching methods, students are given a chance to display their knowledge by solving a problem according to certain criteria, while following the practices that are used in the state-of-the-art industry (Chin, 2006). The consequences of more of this integration may result in further changing and expanding forms of communication and interaction.

This study demonstrates an overview of the state of teaching CAAD in the Department of Architecture, Misr Academy for Engineering and Technology (MET). By use of CAAD software, a collaborative design-based approach has been developed basically to enable students in the second term of the first year to explore new skilful and creative ways of thinking. The students had similar academic backgrounds in prerequisite courses including engineering drafting, descriptive geometry, building physics, building construction, structural engineering, architectural design, and history and theory of architecture. However, the information presented in this study is probably as transient as the fast development in the field of Information and Communication Technology (ICT) and CAAD. It takes stock of what had been planned for and achieved in the academic year 2006-7. The critical aspects of the collaborative design approach, the learning objectives of the course, and the process are consecutively discussed in a way to draw conclusions on proper improvements.

1.1. THE PROBLEM

The research problem is identified as the existing traditional way of teaching CAAD courses in some architectural engineering departments in the Egyptian universities that often reported unsatisfactory learning outcomes.

1.2. HYPOTHESIS

Collaborative design in the sense of this paper is closely related to allowing for principles of CAAD systems to be more appropriate for teaching. In hypothetical valuation analysis, the study examines the necessity of combining ICT with architectural courses' teaching in a collaborative design manner, as a potential to develop and attain better learning outcomes. Further outcomes may be obtained in professional practice within large scale projects, where graduates have to collaborate with consultants from all over the world.

1.3. AIMS

The educational technique of collaborative design is developed to train students to plan, design, and execute experiments through their own self-directed learning, with help and advice from tutors. In this regard, the outlined framework introduced in this study, aims at supporting CAAD educational process with special considerations for characteristics and main principles of a collaborative, interdisciplinary approach. It further aims to evaluate the effectiveness of the course teaching with reflect on what, why, and how improvements would be necessary and possible.

1.4. METHODOLOGY

In a way to attain its circulated aims, the study clarifies some positions about the differences between software-teaching and principles-teaching in CAAD courses, and to show in which context they can be adopted. It is, therefore, determined to approach a framework of terminology which can be used to distinguish the architectural principles' teaching from the computational content provided in the course. The section on collaborative design presents a multidisciplinary approach developed in research work and teaching practice, which was used as an illustration of the framework. The activities in the course were organized into individual assignments and group assigned tasks, while the reflection on students' thinking styles and the design process were key aspects of these exercises. The applied framework included the course's contents, its Intended Learning Outcomes (ILOs) and experiential learning as the main educational approach. Students in a multidisciplinary team were trained to make their own design thinking transparent and listen with interest and respect to each other. In teamwork, students had to organize their group activities and plans and find appropriate definitions and answers to the problems and objectives of the exercise.

2. Related CAAD Education Efforts

Educational systems demonstrate considerable robustness and resilience in the face of both environmental and intended change (Goldspink, 2007). A number of CAAD courses in worldwide universities has been developed to teach collaborative, multidisciplinary approaches, using information technology tools. Sawhney et al. (2002) assessed the nature of collaborative design, learning outcomes and social attitudes of students, external participants, and instructors towards such open cooperative initiatives in a program taught at Massachusetts Institute of Technology (MIT). O'Brien et al. (2003) developed a CAAD course that combined both active and

reflective learning about collaborative design and methods, where students were able to develop process designs for the integration of technology into the work of multidisciplinary design teams. Achten (2003) created a framework for the development of educational processes that allows students to grasp new development, use them in their own design work, and to better reflect on their own position relative to CAAD and architectural design. Khamesan and Hammond (2004) investigated learning effectiveness and proved the importance of personal and interpersonal awareness in synchronous collaborative problem-solving concept.

Van Leeuwen et al. (2004) developed an experiential learning that proved to be a good way for students to realize the need for organizing collaboration processes. Van Leeuwen et al. (2005) proved the necessity of management and organization of the design collaboration process through course teaching. Tubaishat et al. (2006) explored the impact of technology and culture on higher education in two Arab countries, and argued that adoption of technology could provide a comparable learning environment to students in these countries. Golspink (2007) provided a grounding point for developing a set of principles to guide future educational reform. These principles draw on a well established set of ideas in terms of loosely coupled layout and recent advances to more efficient educational management.

2.1. MOTIVATION

These existing courses and developed systems indicated above were found excellent additions to the Architecture, Engineering, and Construction (AEC) curricula, as they fostered students' active learning experience in multidisciplinary terms with the gained insights and generated guidelines for the development of collaborative CAAD courses. Yet, a room for innovation to better accommodate a process focus and to provide students time to reflect on and integrate their experiences still exists. In this regard, the developed course was designed to provide students with the tools, not just to analyze and solve a given exercise, but also to improve some intellectual aspects of CAAD principles. Another key distinction of this developed course from others taught in similar department programs in the Egyptian universities is that many of these courses still employ experimental software solely that may not support specific aspects of the collaborative, multidisciplinary approach. Besides, the use of such software may provide the students with limited opportunities to directly apply their learning in practice. While there are limitations to cover and update all related commercial and experimental software products available, a decision was made to give students the potential to explore more of the principles' teaching of CAAD, in terms of social, professional, educational, and innovative systems, with focus on the architectural content and improvement of thinking styles and creativity.

3. Collaborative Approaches in CAAD Teaching

The following principles reveal the potential benefits of using collaborative, multidisciplinary approaches to improve the teaching processes of CADD courses. Unlike the rationalist methods and traditional teaching approaches, the alternative model emphasizes the need for a focus on the human factor, relationships, collaboration, and communication learning prospects, rather than structures and centrally determined standards and conformance.

3.1. SOFTWARE VS. PRINCIPLES TEACHING IN THE CAAD COURSE

This part aims to clarify some positions about the differences between software-teaching and principles-teaching in courses that apply CAAD, and to show in what context they may be related. Considering the use of computers in education, Achten (1996) distinguished four kinds of computer systems in education: social; professional; educational; and innovative systems as illustrated in Table 1.

TABLE 1. Software vs. principles' teaching within CAAD-curriculum (De Vries, 2007; Achten et al., 1999; Achten, 1996).

	SYSTEMS			
	Social	Professional	Educational	Innovative
Description	Computer tools that all student should be able to use; e.g. word processing, presentation, web search, information retrieval systems, and spreadsheets	Computer tools used in arch. practice; e.g. CAAD software, calculation software, and GIS.	Dedicated computer tools to convey specific purposes; e.g. AutoCAD, net browsers, and rendering software, multimedia.	Computer systems that reach beyond the state of the art of professional systems; e.g. automated plan recognition and virtual reality systems.
Computation	Database Structures, Computer basics, etc.	Models, software basics, data, publications, exchange formats, etc.	Programming techniques, prototyping, building systems, information handling, etc.	Design systems, modeling techniques, interface design, etc.
Architecture	Cost calculation, facility management, data transfer, data exchange, etc.	Production drawings, simulation, evaluation, etc.	Analysis leads to a classification of design concepts, design strategies, building analysis, etc.	Construction planning as a critical factor in building management, design synthesis, form generation, etc.

It seems necessary to make a further distinction that will enable to see the differences between CAD and CAAD. This distinction can be found by considering automated design systems as instruments, and by the requirement of computational systems of rigorous and consistent definition of their properties (Oosterhuis, 2004).

3.2. COLLABORATION

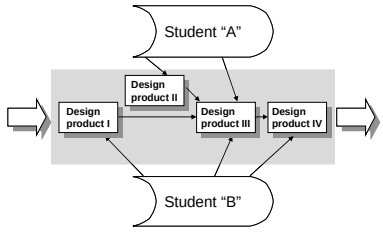
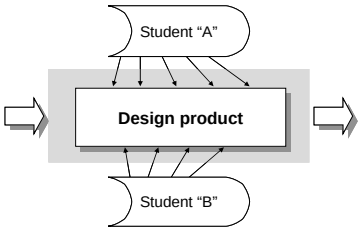
One of the first issues in utilizing the collaborative approach in education is to convey an understanding of what the term 'collaboration' means. Van

Leeuwen (2004) notes that cooperation relates to working together for mutual benefit, while collaboration relates to working together to achieve shared goals. The main distinction between the two forms of working together is the creative aspect of collaboration. In other words, Sawhney (2002) describes collaborative design as a process of creating and sharing knowledge by working together on an actual result.

3.3. LOOSELY AND CLOSELY COUPLED PROCESSES IN EDUCATION

Two areas of theory have proven useful—that of Karl Weick, who proposed that educational systems be viewed as 'loosely coupled' and complex adaptive systems theory known as 'closely coupled' (Goldspink, 2007). Van Leeuwen (2004) distinguishes closely coupled processes, in which participants continuously work closely to realize a design, from loosely coupled, where each participant contributes form a particular domain expertise at moments when he/she has the knowledge required. Table 2 compares the two systems in terms of the process layout and configuration.

TABLE 2. Loosely and closely coupled processes (Fusarelli, 2002, and Hagel, 2002).

	Loosely Coupled active process	Closely Coupled active process
Layout		
Configuration	□ No direct connections between the modules, persistence, buffering, adaptability, satisfaction, and effectiveness anticipated results. □ Does not require coherence between the system parts to remain viable. □ Implies slow diffusion of central initiatives with large-scale change. □ Active experimentation in a context of trust. □ Maintained focus on outcomes and core values. □ Providing richly connected structures around a certain curriculum. □ Failure in one module does not affect the system.	□ Interconnection among system ingredients. □ Tends to improve based-on experience with particular tasks. □ Incurs significant coordination overhead as the number of participants increases. □ The most common justification for maintaining non-standard or secret formats is the desire to keep them closed; i.e. to prevent the introduction of innovative new systems developed by others. □ Failure in one module results in the failure of the entire system.

Loose coupling within education systems has been variously interpreted. Its utility as an organizational construct is currently guiding educational systems toward that of fragmented centralization, in which policymakers can have greater opportunity to craft more coherent, systemic education policy amidst competing demands for limited resources (Fusarelli, 2002). Even when designing closed systems, the open standards should be adopted to

ensure that access to them can still be provided with minimal effort. A multidimensional coupling (formal, informal, rational, and emotional interactions) should be established among the agents (teachers, principles, and faculty) constituting the loosely coupled process (Goldspink, 2007).

4. Proposed Methods and Study Protocols

4.1. THE FRAMEWORK APPLIED TO THE COURSE

The CAAD course using collaborative approach that is developed by the author aims to teach skills of how to organize, enhance, and communicate, and to provide students with insight in the particular complexities of distant collaboration in multidisciplinary design projects. In light of the principles' teaching approach, the technologies illustrated by Rossignac (1999) seem to be still valid and relatively ubiquitous, Figure 1.

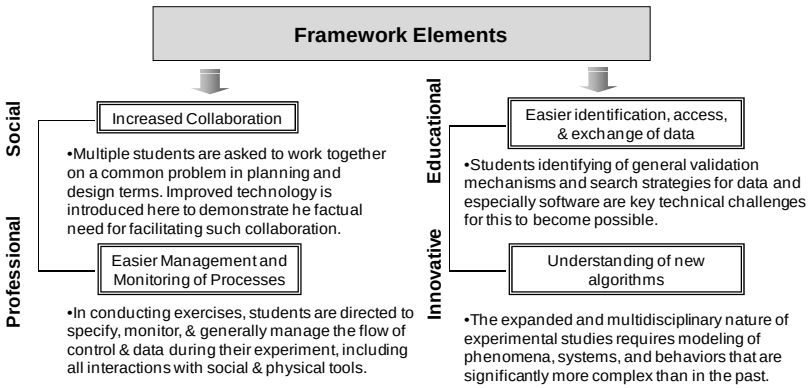


Figure 1. Definition of the framework elements (modified from Rossignac, 1999).

4.1.1. Course contents

The course allows students to experience a number of CAAD software and tools and their use in architectural studies. This direct experimentation phase occupied one half of the students' coursework. A series of 14 lectures by the author, supported with 14 lab exercises by assistants provided a framework for understanding concepts, issues, and state-of-the-art practice in computer applications in architecture. Based on these lectures and discussions, students reflected on their own experience with developing thinking styles to produce a revised process to improve future collaborative efforts and creativity. Collaborative design processes were introduced in the course through team-working skills that were fostered via group, task-based practical exercises. In these exercises, students were asked to work together on a common problem in planning and design terms, while improved

technology was introduced to demonstrate the factual need for facilitating such collaboration.

4.1.2. Intended Learning Outcomes (ILOs)

The ILOs and methods used to achieve them in terms of organizational instruments and ICT-related tools are illustrated in Figure 2.

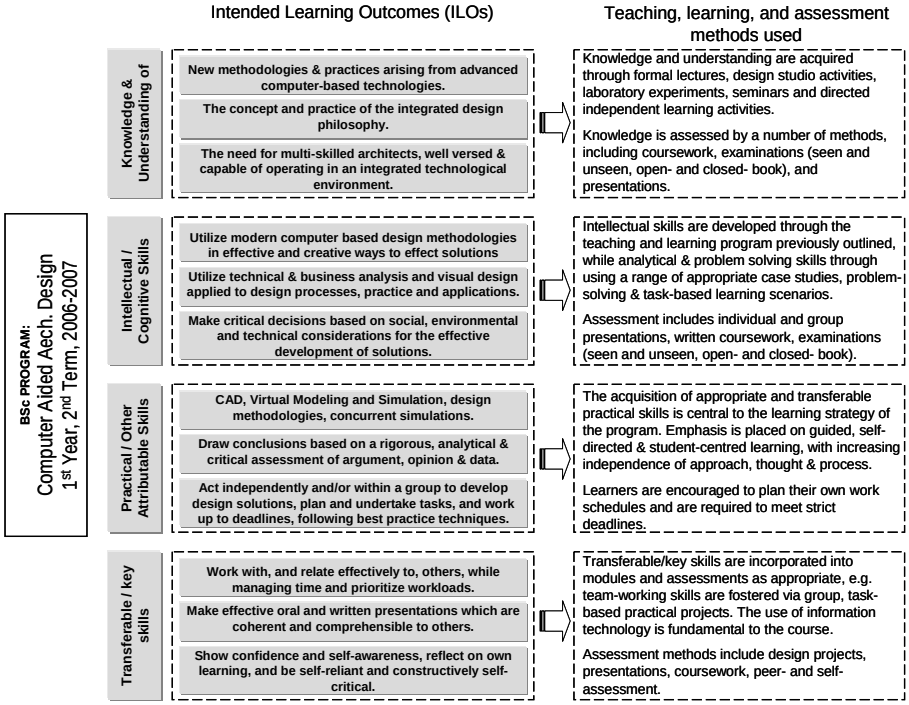


Figure 2. The ILOs, and the means by which they are achieved and assessed.

4.1.3. Experiential learning

The educational approach that was chosen in this course can be indicated as 'experiential learning.' This means that the student acts as an active learner and that the teacher's coaching role is focused on the student's activities. According to the American Institute for Experiential Learning (Van Leeuwen, 2004), this educational concept is composed of three components; knowledge, activity and reflection, Figure 3.

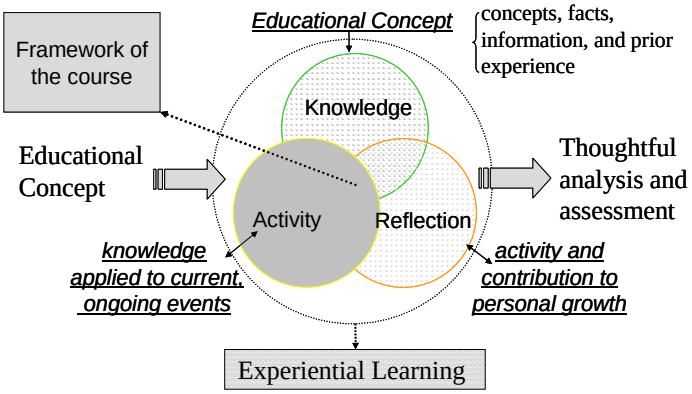


Figure 3. Experiential Learning as the core concept of the collaborative approach.

4.2. THEMATIC LECTURES IN TASKS

In these lectures, the objective was to make students aware of the many social aspects to collaboration, such as the need for mutual acceptation, openness, commitment to shared goals, shared responsibilities, etc. (Jennings, 2003). The activities were organized into five assignments, of which two were individual assignments and three were group assigned tasks, Figure 4:

- *Literature review*. Each student prepared a summary and short presentation of a review for two scientific papers on CAAD programs.
- *Working in a team*. Student are grouped in multidisciplinary teams, within which they represent various construction-related themes (architectural and structural design, presentation, HVAC and building technology, etc.)
- *Individual final report*. Every student writes a report on his/her experiences with the course, describing what he/she has learned and providing an evaluation of the ICT-tools that have been utilized.

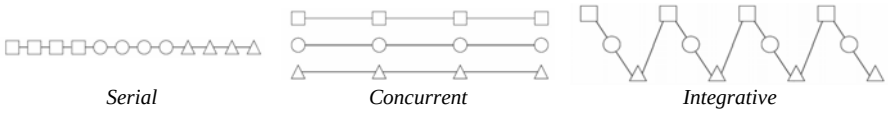
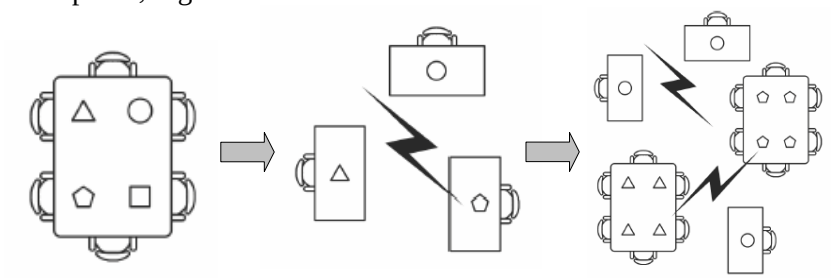


Figure 4. Alternative approaches to collaborative work (O'Brien et al., 2003)

In the year-work assessment, student workload of this course was 78 hours. The course was described on delivered CDs that included all necessary information about objectives, tasks, literature, time planning, relevant web links, requirements for deliverables, presentations, lecture notes, reflection criteria, etc. Students' contributions and the results of

activities in these tasks were submitted in the form of emails and softcopy for each phase, Figure 5.



Task 1: Working in a team (all themes involved and interlinked)

Task 2: Working in a distributed team (individuals working on distance)

Task 3: Working in a distributed set of organization (similar thematic groups reorganized for discussion)

Figure 5. Collaborative design in tasks (modified from Van Leeuwen, 2004).

4.2.1. The use of ICT tools for collaborative design

Progress achievement in the course required two types of communication, (1) One-way asynchronous dissemination of research results or problem solving, used in students' individual research efforts; and (2) Two-way synchronous and asynchronous communication between team members (Rossignac, 1999). In developing the CAAD course teaching, the developed approach required students to create a web page to present their efforts on drafting and modeling. The ICT tools that were mainly used in this course were Office and Net-meeting (Microsoft), AutoCAD (Autodesk), and web search engines. Students were given an access to computers equipped with hardware and software that were relevant and efficient for the course.

4.2.2. Ways of working with CAAD in the collaborative process

Although learning a set of CAAD skills has its advantages in its own right, it was useful for students to be prompted into more refined ways of working with the computer in the design process. In general, students could learn these skills in the ways illustrated in Figure 6 (Achten, 2001).

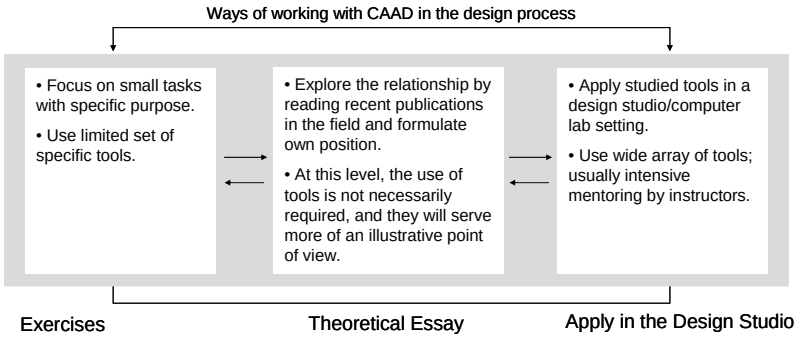
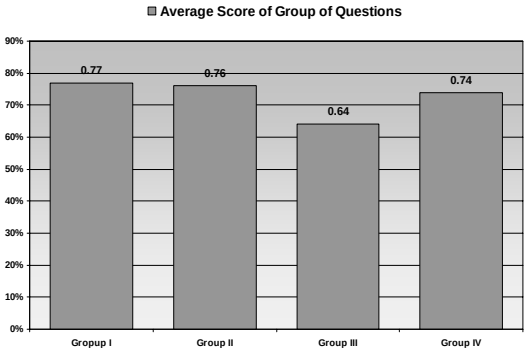


Figure 6. Teaching transferable Skills through CAAD.

4.3. ASSESSMENT METHODS: CATEGORIZATION AND RESULTS

Key methods of assessment were taken as the following:

1. *On-line Questionnaires:* to assess students' own articulation of their background and motivations (to be further probed in the interviews).
2. *Examine On-line Usage Data:* to categorize students' roles, types of interactions, and sequence of emerging activities online.
3. *Observational Case Studies:* to understand group dynamics, artifacts produced, and process of collaboration within/outside each group.
4. *Intensive Interviews:* to assess understanding of students' personal motivations, concerns, and views in the evolving educational process.
5. *Instructor Observations and Assessments:* as instructors were asked to assess teamwork and provide additional validation, Figure 7.



Group I: Questions to assess knowledge and understanding.
Group II: Questions to assess intellectual/cognitive skills.
Group III: Questions to assess practical, research and independent learning skills.
Group IV: Questions to assess transferable/key skills.

Figure 7. Assessment categorization and reported results taken out of the final term exam on a total of 56 students in the class.

5. Course Evaluation

To be able to assess and improve the course, it was necessary to evaluate both content and format. The evaluation form inquired about the effectiveness of the educational approach, the level of competences, self-development within the collaborative approach, efficiency and sufficiency of the acquired skills, students' capability of using the tools on their own initiative, their ability to integrate the organizational and technological skills in their foreseeable practice, and others. Answers to these questions have been obtained through individual reports of the students contained information, regarding their personal reflection on the course and the learning experiences. In these reports, information regarding the collaboration process during the assignments was found, motivating the

analysis of these processes in terms of activities, roles, and tasks, and their experiences in participating in teams and in using organizational instruments and ICT tools.

5.1. EVALUATION RESULTS AND ANALYSIS

The main conclusions based on the individual reports by the students were:

- The weak principled distinction between software-teaching and principles-teaching when it comes to computational issues of design systems.
- Most students were aware of an experienced new kind of thinking style.
- Working in a team of people previously unknown to each other has a significant and positive influence on the learning experience.
- Students were actively aware of and concerned with both their roles as members in multidisciplinary teams and responsible individuals.
- Organization of the collaboration is crucial for the success of the process.
- Students' reflection both on the work of their teams and individual contribution was the most difficult part of the practical learning pattern.
- Sufficient skills with ICT tools were necessary.
- Students appreciated the digital completeness of course material on CDs.
- Students rated this course by 3.36 on a scale 1-5, Table 3.

TABLE 2. Students' evaluation of the course.

Course Evaluation Items	*Points*
Effectiveness of the educational approach and the targeted competences	3.11
Logical sequence of teaching material in the course	3.65
Suitability and relevance of tutor marked assignments (TMAs)	3.92
Self-development with respect to the domain of collaborative approach	3.75
Suitability and relevance of support/teaching aids to teaching material	2.78
Adequacy of tutorials in covering course content	3.67
Clarity of course requirements	3.29
Acquired sufficient skills using the tools for distant collaboration	3.45
Quality of the production of support/AV material	2.64
General Course Evaluation	**3.36**

- The appreciation for the ICT tools varied: 35% effective; 19% too simple; and 46% too complex.
- Students agreed that the course format stimulates active participation.

6. Conclusion

- A satisfactory level of collaboration is not easy to achieve with students that are traditionally trained in cooperation and coordination. Much effort is needed to convey the notion of collaboration.

- The framework developed as the conclusion, allowed students to grasp new development, use them in their own design work, and to better reflect on their own position relative to CAAD and architectural design, Figure 8.

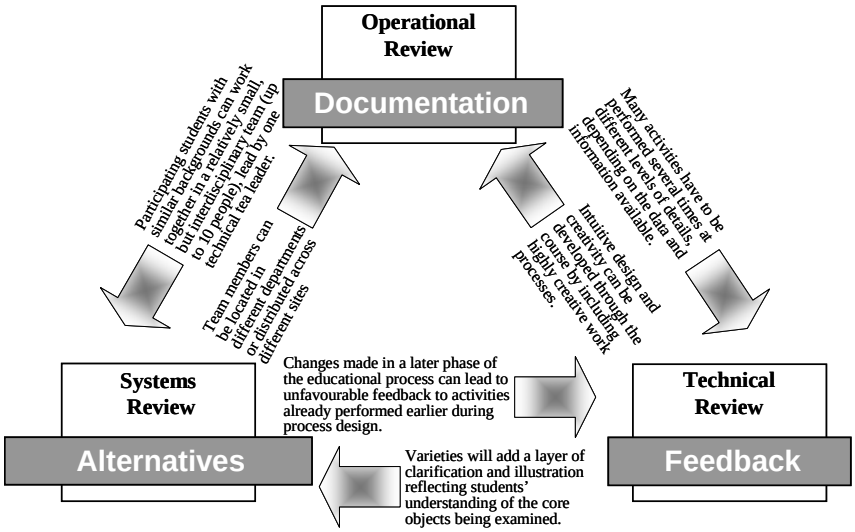


Figure 8. Conclusive output of the CAAD course.

- Opposite to traditional practice of individual design process in design classes, students in teams became more willing to learn from each other and realize that only in this way; a good and integrated result can be achieved.
- Experiential learning is a very good way for students to organize collaboration processes. Providing students with advanced tools of theory and practice while discussing such issues in groups, has yielded an increased effectiveness in learning through experience.
- It appears that there is no principled distinction between software teaching and principles' teaching when it comes to computational issues of design systems. When the architectural content of CAAD systems is concerned, the CAAD principles will seem to be more appropriate for teaching.
- Collaboration can only generate economic value when it is firmly anchored in certain processes that span across system ingredients. New generations of information technology can be significant enablers and facilitators in teaching and delivering CAAD courses, but much progress can be made with technology that is already available.
- Collaborative attitude equipped with ICT tools had a beneficial effect on students' attitude and enthusiasm for the course material. They allowed for better management of its processes in terms of data exchange, structuring data files, and experiencing how to agree upon a document/CAD standard.

7. Recommendations

This practical example provided a grounding point for the development of a set of principles to guide future CAAD courses reform:

- To address the structural barriers to effective multidisciplinary activities, the appropriate facilitators in educational and research community as well as in the industry and government can foster collaborative research in state universities by providing funding explicitly for multidisciplinary projects, extending the scope of the few such initiatives currently in place.
- Being well aware that a completely automated procedure is probably not feasible, new generations of IT can be significant enablers, while allowing for progress to be made with technology already available.
- The technological transition should be started immediately because lengthy-lead times are required to build the necessary skills. Educational institutions should consider an immediate adoption of this transition, as lengthy lead-times will be required to build the necessary skills.
- There is a need to give more concern to the architectural content of CAAD systems in the way that will allow principles of CAAD systems to be more appropriate for teaching.
- Besides the students' personal reflection on the course and the learning experiences contained in their individual reports, a formal evaluation should be carried out by a departmental evaluation officer in the form of a written enquiry among all participating students. The results of this enquiry may be targeted at giving insight in the perceived relevance of the course objectives, the quality of the course and the assignments, the time spent by students, the learning yields, etc.
- While experiential learning proved successful in general, the effect may be increased by giving the students an overview about the approach.
- With respect to quality improvement and accreditation requirements, external examiners should be considered and appointed in order to:
    - review coursework assignments and assessment criteria;
    - approve examination papers;
    - monitor standards through moderation of completed assessments;
    - attend Examination Boards; and
    - participate in the course review processes.
- Long-term social and individual benefits should be focused as a central target for improvement rather than short-term outputs.
- Change comes from the 'inside out' as active experimentation is encouraged and supported in a principles based framework. This emphasizes that micro (site/group based), loosely coupled intervention is to be preferred to macro, closely coupled (system-wide prescription).
- In-class educational approach should consider smaller groupings of committed students, while opportunities established to allow for these

groups to interact, share (ideas and members) and ensure groups address diverse focal points to widen the search for fresh insights upon which to base action for improvement.

8. Future Studies

Future development for improvement of this course should focus on redesigning the tasks and probably adding smaller exercises. Added exercises may focus on a more limited number of aspects of collaborative work. For example, separating the focus on principles' teaching of CAAD from that on professional roles in software teaching is preferable in early exercises, while they can be combined again in later experience to increase students' awareness of the differences and influences on their behaviors.

Acknowledgements

This paper reports from the state of CAAD teaching in the Department of Architecture, Misr Academy for Engineering and Technology (MET), in the Academic Year 2006/7. The primary technical data for the preparation of this course were the innovative design methods for CAAD methodology teaching in Eindhoven University of Technology, and the principles of developing an open collaborative framework for future curricula set by MIT Program in Media, Arts, and Sciences. Hence, the author would like to acknowledge them all, thank the teaching assistance team in MET, and feels indebted to all researches and developers of the attributed valuable ICT components used particularly in teaching CAAD course in one way or the other, and in the architectural education development in general.

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