Information Communication Technologies in Architectural Education

Authors:

Modris Dobelis, Riga Technical University, Riga, Latvia, dobelis@acad.latnet.lv

Abstract *¾ Nowadays Computer Aided Architectural Design (CAAD) undoubtedly is recognized as a design media rather than a design tool and is widely accepted in architectural practice. The general goal architects want is to visually express design and illustrate their projects or ideas using both professional experience and personal computerized creative skills. Currently rapid advancements in the growth of information technology which are used to communicate architectural design projects. CAAD is a particularly dynamic field that is developing through the actions of architects, software developers, researchers, technology, users and society alike. The paper deals with the teaching of information technology in architectural schools. The delivery of CAAD knowledge is discussed. Academic courses basically are about the development of computer aided creative and problem solving skills in context with fast changing CAAD media. It is more difficult to teach the common principles behind the software which are general and will most likely survive ever-changing software versions. Limited credit points for the subjects do not allow developing detailed courses for training particular software. An evaluation of the promptitude of the architectural students at Riga Technical University for the self-sufficient problem solving tasks was performed. Four different computer based design tasks were given to the students using the same massing model of building. The statistical analysis regarding an average time required to complete the exercises and correlations between different skills is presented at the conclusion. Further developments of architectural problem solving are discussed for implementation into the education system.*

Index Terms *¾ 3D Modelling, Architectural Education, Computer Aided Architectural Design*

INTRODUCTION

Computer Aided Architectural Design (CAAD) undoubtedly has become a recognized design media rather than design tool and is widely accepted by architectural practitioners. The general goal architects go after is visual expression, design and illustration of their projects or ideas using both professional experience and personal computerized creative skills. Currently rapid advancements in information technologies which are used to communicate architectural design projects. CAAD is a particularly dynamic field that is developing through the actions of architects, software developers, researchers, technology, users, and society alike.

The rapidly developing technology of the 21st century has transformed the general use of computers into a specific, convenient, and necessary tool for professionals [1]. With great success they are also used by architects. However, architects often face problems associated with the peculiarities of user-computer interface that was inherited from the times when computers were only used by computer professionals for the purposes other than arts, and these features were not user friendly. Considering the architects professional needs and expectations, the development of user friendly human-computer interaction is of topical importance today. Different types of computer aided interaction techniques are available in contemporary architectural design practice, which respond to the various kinds of requirements for these tasks.

Using virtual environment to visualize design ideas from the very first initial steps, the architect is challenged to deal with perception of space, solid and void, without translations to and from a two dimensional media. At this stage we may expect innovation of design expression. The potentials of computer aided systems used for architectural design solutions in many cases are way ahead of the average users' level of competence and skill.

Wider access of Information Technology (IT) and the rising involvement of architects into the computer-aided technology lead to the discontinuity in the architectural oriented computer literacy education. As a result one can face with the situation when the students often use the computer pell-mell, basically as a powerful 2D drafting tool. This situation is determined by the majority of the architectural Institutes which still make use of traditional design methods lacking the power of 3D, 4D or even 5D modelling possibilities. In order to establish the architects' intended goals, some formal specifications, standards and prototypes are required by the increasing needs for effective design information communication both in architectural practice and education.

BASIC STAGES IN ARCHITECTURAL CONCEPT DESIGN

To automate the whole architectural design process one should have a clear understanding about what should be done and what is possible to be performed with particular computer tools or media [2], [3]. There are several stages in the classic process of architectural concept design. Point, shape, functional volume, and zone – these are the classic sketch

elements architects use while starting to develop their initial design. Taking into account proportions and geometric relations, the outlines of the object are refined and frontal composition is determined. A massing model in a preliminary stage of the design is dimensionally accurate summary of the fundamental exterior forms of a building. Typically it is represented with solid blocks and does not include any hollow elements. Door and window openings in walls are not shown. Building details as well are left out entirely.

In the next stage the internal spatial structure is specified in more details – walls, columns, ceilings, flat or sloped roofs identify the spatial composition. Because the architect thinks in 3 dimensions and interprets the objects through planes, the initial lines are further transformed into planes. At this stage the corrections of initial elements are performed and first models and mock-ups are created.

Constructional elements are edited by changing their size and location in the plan view. A new mock-up normally would be created again. Additional elements like vertical and horizontal communications are located in the constructional frame and volume. They organize the relationship between rooms. In this stage besides the determination of the interior and constructional solutions the exterior is formed as well. An attempt to ignore the right sequence of these design stages will result in failure – the unity of basic elements in plan, section and elevation will fall apart. New corrections and new mock-ups are required again.

The next stage is complex development of the facades. Based on the constructive structure the architect finds several design solutions. New mock-up helps to better understand the interaction of volume and massing in the development of composition.

Corrections in the planning structure may be required in the final stage of the concept design between elevation and plan views. Only now interior and finer detail design solutions are being considered. High level visualization materials will greatly benefit the quality of project presentation. And finally the last stage will be the drawing preparation and project completion.

CAAD TASKS AND CHALLENGES

The first practically application of CAAD solutions occurred approximately two decades ago included 2D drafting work automation. AutoCAD dominated in the second generation CAD software [4] business, oriented for civil engineers. Structural engineers have been the earliest users of design computing tools among the design professionals in the construction industry. AutoCAD has a unique situation because it has the largest segment of the CAD design industry. Engineers outnumber all architects and interior designers combined by more than 20 to 1. AutoCAD will be used even in cases where it is not the best tool for the task. One of the reasons for this is the AutoCAD file compatibility – today practically any CAD software can create DWG or DXF files. Gradual increase of both the computing power and software performance allowed the solution of more complex designs.

The preparation of the design documentation for a building project is just one of the main tasks in architectural practice. Besides this, contemporary CAAD potentials can be successfully used for preparation of highly realistic images with material textures, sun and light studies, animation and Virtual Reality (VR) presentations including computer game-based ‘walk through’ studies of the new design project. Some of the later tasks were not available using the conventional design method previously used. Development of interoperability standards is a complex task [5]. International Alliance for Interoperability (IAI) is leading the charge and has established software standards. To enable more data sharing, IAI developed specifications, called IFC (Industry Foundation Classes). Those define building based on objects such as walls, doors and windows. Using a common object-based model instead of a drawing based project software products can more readily share the same data for different tasks. Project data during design could be shared between various software products for solving different tasks varying from architectural design, structural analysis, energy analysis, quantity estimation, code checking, and building management through all its lifecycle after the construction has been completed.

As a rule, the first stage in the implementation of the VB concept is the design of three-dimensional model in the computer. The greatest difficulty for the students while studying these issues is to acquire the three-dimensional visual skills. Not so long ago this knowledge was extensively taught in the subject Descriptive Geometry. Nowadays students have enormous complications if these problems are considered in the old fashioned way with pencil in ‘black and white’ on paper when everybody has powerful computer nearby. However, the ability to successfully manipulate the fashioned design tools and media highly depends on the basic engineering graphics communication skills. Several attempts have been made to improve the teaching methods, which master the spatial perception abilities [6] and develop 3D design skills using the latest achievements in information communication technologies.

Tasks for educational purposes are even much wider – they can be the basis for creative studies, being the media for formation of professional thinking for the student. However, the absence of professionally oriented education methodologies has lead to the situation where the students use the computer as a powerful 2D drafting tool which serves as a replacement for rapidograph. The reason for this is a bad experience. Typically many students work part-time in architectural firms or companies who have adopted the first CAD tools years or even decades ago. Basically the students complete the mission a draftsman in a ‘little computerised way’, but basically the technology has stayed at the same conventional ‘drafting design’ level with limited possibilities of process automation. The real concept of building design using contemporary information technology has changed during this time dramatically. The power of modern 3D design

software provides more efficient and productive way of preparing design documentation and visualisation materials at the same time.

University curricula should not include the subjects being just like qualification courses for some particular CAD software, most often AutoCAD, training. However, there is no doubt that every university graduate should be familiar with general 2D computer drafting principles. Practical skills of 2D drafting are mentioned in job advertisements as a requirement. The development of spatial or 3D thinking in architectural practice is extremely important and requires quite a bit of effort and time to master these skills, especially now using the new design media based on wide application of IT. Methods and management of introductory design education is becoming a key question in many curricula throughout the world [7]. However, tight university budgets for IT involved in a design study is a problem not only for universities in developing countries, but also for Western universities with more advanced level of technology usage. The fast rate of hardware and software upgrading force the universities to spend much effort and resources on finding solutions not associated with the primary focus – education. Overcoming this obstacle is based on the development in curricula subjects the design solution approaches which do not depend on the level of technical equipment.

COMPETITIVE ARCHITECTURAL SOFTWARE

Nowadays, the building industry requires a more productive work schedule [8]. Architects must change their design habits to adopt the new challenges. The working media has to be changed now – from plane to space, from drawing to solid model. Nevertheless, the thinking still is the same – three-dimensional. In architectural design process, we can define three phases: an investigation of the form, a technical documentation, and a presentation. Current architectural CAD systems lack the ability to provide first sketches – they could not be a substitute for pencil at the conceptual phase of a project.

The third generation architectural CAD [4] software successfully combines 3D modelling and 2D drafting features. One of the leaders in this class – ArchiCAD is oriented to the design of all basic architectural elements in 3D, quickly producing floor plans, elevations, and sections, providing photo-realistic images, animations and VR scenes from the same shared object model. ArchiCAD includes large project file handling capability via hotlinks, programmable database language extensions for advanced cost estimations. The new construction simulation capability could be linked to Microsoft Project documentation.

Many of the contemporary CAD systems are basically oriented on 3D model design. In the building industry a concept of VR has been used for quite a while [9] and it provided several benefits. Advanced IT solutions provide the opportunity to implement sophisticated distributed systems for collaborative design. Before the actual building has been constructed it is possible to test different design, construction, usability and even demolishment aspects in the Virtual Building model. Persons with different interests and competencies in the building process such as architects, installation engineers, structural engineers, electricity engineers, clients, builders, and design managers can all be brought together in a distributed design space where the VB is drafted, designed, built, and functionally evaluated. A design space created in an object-oriented and parametric VR environment enables to simulate realistically and efficiently several variants of the form, function, construction, and use of the building yet under consideration. Therefore, nowadays even the architectural students have to start to implement the IT knowledge into their specific needs from the very first study year otherwise they might become 'the slave of the tools and not the boss' [10]. A serious misconception is when the teaching of engineering graphics is limited just to the training of how to use particular CAD software. Even worse is the case when the CAD teaching is restricted to studying just the 2D features.

TARGET AUDIENCE ANALYSIS

The duration of bachelor studies in architecture in Riga Technical University is 7 educational periods of 16 weeks of study semester plus 4 weeks exam session. Compulsory subject 'Computer Applications in Architectural Design' is limited to 2 credit points and taken in the fifth semester. In this course the students for first time are allowed to use computer aided drafting and/or design methods in their architectural design projects. Because the architectural students' background knowledge level is so different and it is changing fast from year to year, at the beginning of the semester they complete a questionnaire about individually acquired computer skills so far (Table 1).

Study Semester	Students Questioned	Percentage from all							
		Owns PC	Different Software Usage Skills						
			Auto CAD	Archi CAD	Micro Station	Other CAD	Corel Draw	Photo Shop	Other Paint
1	36	81	28	19	0	6	36	56	22
5	37	97	78	51	3	8	49	70	11

TABLE 1
AVAILABILITY OF PC AND PREVIOUS COMPUTER KNOWLEDGE OF THE STUDENTS IN ACADEMIC YEAR 2003/2004

In the 5th semester practically all the students now have their own personal computers. During their studies 78 % of the students have already acquired AutoCAD drafting skills and work part-time in architectural companies. Practically in almost all instances they perform 2D drafting work with just a few exceptions of 3D modelling work. As No. 2 software in Latvia used by practitioner architects for 3D modelling and documentation preparation is ArchiCAD. PhotoShop is No. 1 for raster graphics processing, typically for the preparation of visualization materials.

The time spent by students learning to use AutoCAD is represented in Table 2. When the students enrolled at the university 2 years ago, 21 % of them were already familiar with AutoCAD. First semester studies are the most difficult ones – only 14 % find time to learn 2D drafting with AutoCAD.

Study Semester	Percentage from All
Before University	21
1	14
2	24
3	17
4	17
5	7

TABLE 2
TIME WHEN 5TH SEMESTER STUDENTS LEARNED THEIR AUTOCAD SKILLS.(TOTAL NUMBER OF STUDENTS QUESTIONED – 42 (2004/2005 STUDY YEAR)

DIGITAL MEDIA TRAINING IN ARCHITECTURE

The main teaching concept in the subject 'Computer Applications in Architectural Design' is to inform the students about existing complex CAAD solutions available on the market today, giving them some compulsory practical training or warm-up exercises, followed by individual design projects to develop their ability and skills to have a good command over computer applications for architectural design tasks. The aim is to provide the students with an insight into the context and complexities of architectural design, and their future responsibilities.

Since only 7 % of the students by this time are not familiar with 2D AutoCAD drafting, it is not taught at all in this course. To prove their 2D drafting skills a massing model design exercise is given as homework to be solved using any 2D CAD software. Exercise is exactly the same they solved in the first semester in the course of Descriptive Geometry about intersections (Figure 1). The 2D solution (plan view and elevation view) has to be handed in printed in scale on A4 size. The used version of CAD software should be indicated and the time required to complete the exercise should be recorded (Table 3).

A) EXPLANATIONS IN THE LECTURE FOR GDL SCRIPTING EXERCISE

B) SOLVED 3D MODEL EXCERSIZE USING SKETCHUP SOFTWARE

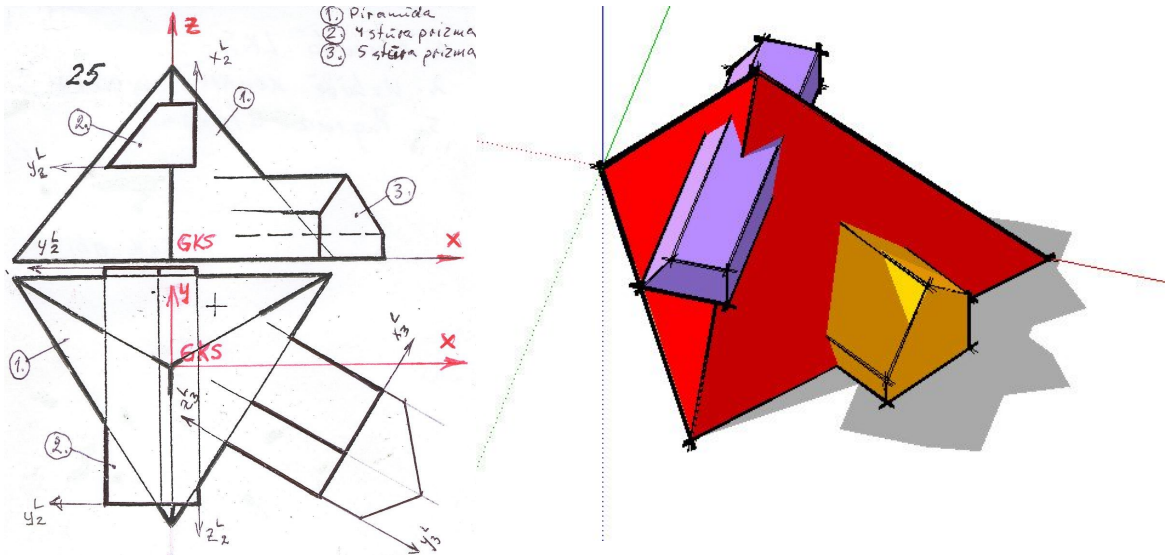

FIGURE 1
EXAMPLE OF DESIGN ASSIGNMENT 'INTERSECTION OF OBJECTS'. TO BE SOLVED IN 4 DIFFERENT WAYS.

Average Group		Two 2D Views, any CAD	3D Model, SketchUp	3D Model, ArchiCAD	3D Model, GDL Script
Total Average Time		61	39	96	112
Students' Reported Level of Competence in ArchiCAD	1 – low	66	40	113	114
	2	57	32	110	107
	3 – medium	45	29	38	105
	4	55	73	48	135
	5 – high	25	20	7	40
min Time		10	10	7	15
max Time		240	90	600	300

TABLE 3
THE AVERAGE TIME REQUIRED TO COMPLETE THE SAME DESIGN EXERCISE USING 4 DIFFERENT SOFTWARE FOR DIFFERENT GROUPS, MINUTES. (TOTAL NUMBER OF STUDENTS QUESTIONED – 46, 2004/2005 STUDY YEAR)

Introductory computerized design, as the initial step in architectural education, nowadays is of crucial importance. In this course students are supposed to acquire values, knowledge and skills which create a basis for further levels of professional education. The success in the training to model real 3D object is in the development of the talent to build it up from simple geometric primitives maintaining the required spatial relationships. It is envisaged that this approach will encourage the students to work through problems in the innovative and thoughtful ways, developing the skills they will need to cope with a rapidly changing IT world.

Quite a long time architectural concept design sketching software resources were extremely limited. New software has recently appeared to fill the existing gap. SketchUp from @Last Software Company is deceptively simple and powerful tool for creating, viewing, and modifying 3D ideas quickly and easily. It was developed to combine the elegance and spontaneity of pencil sketching with the speed and flexibility of today's digital media. Recently a 3D design approach was implemented in the subject through SketchUp. Students find to learn and use sketching in digital versus traditional media very easy. The average time to complete an individual exercise was 39 minutes, including the learning time from multimedia tutorials. However, it was difficult to separate the learning time from the pure time for design solution. Only a few students were familiar with this software before classes. Surprisingly, but the fact is that many architectural companies find out about SketchUp from the practising students.

Third exercise was the development of 3D model using newly introduced to the students ArchiCAD software. After overview lecture about basic principles of design and instruments used students were required to practice individually. Only three basic 3D tools – slabs, walls and roofs – were required to master the basic spatial modelling skills and to complete the same exercise. The average time to solve the exercise was 69 minutes. Students had to self evaluate their expertise level in ArchiCAD from 1 to 5. About 28 % of the students reported their expertise level higher than introductory. Those reporting the highest level of competence solved the exercise within 7 minutes average, while for the beginners and second level it took approximately the same time 113 and 110 minutes, correspondingly. Linear correlation analysis between the time to complete this exercise and competence level is -0.93.

The fourth exercise was devoted to the Geometric Description Language or GDL which is a programming language inside ArchiCAD. It is very easy to learn BASIC type programming language having very close relations with descriptive geometry problem solutions. Some algebraic knowledge is required as well. In order to bridge the individual concepts and processes of multiple design disciplines, intensive cross-disciplinary communication and information exchange starting from the very early stages of design is necessary. This quest for integration has become one of the key issues in building design practice today. About six academic hours were spent on GDL lectures with numerous demonstrations of practical examples. To prove their understanding the same assignment exercise has to be done using GDL language. The script includes operation with basic geometric primitives – prisms and pyramids – and coordinate system manipulations or transformations. This was the most difficult task for the students. The average time required to complete the exercise was 112 minutes. Only the students reporting the highest level of competence in ArchiCAD solved the exercise on average in 40 minutes which is 2.8 times faster than the rest of them.

Introductory design project was aimed to develop the proficiency in representing the surrounding world through the lens of specialized computer aided solutions. The ability to abstract the reality through the associative patterns is being developed through the design project 'Unlimited possibilities with limited resources'. It includes 3 components – the main aim is a free choice composition project, design rules are limited with the use of only some selected features of 3D software and computer serves only as an instrument. Additional unlimited resources used in the project include colour, texture, light, visualisation and animation. The students are supposed to develop professional thinking during this compositional training with ArchiCAD. The task is to facilitate a personally innovative way of employing the computer as an analytical or communicative tool in design. The project has to be presented on one A4 size page, submitted in digital form and supplemented by animation movie.

Digital imaging, digital painting, alternative 3D modelling, 3D animation movies or walk-through, VR, 3D printing are issues covered in the subject only theoretically, primary because of the limited technical resources. The subject

content is constantly revised each year to allow for the ever changing situation in CAAD tendencies in the world and taking into account the existing possibilities.

Final project is demonstration of computer technology skills in preparation of A1 size digital poster. In an exam besides the theoretical question and practical task the students have to explain their feelings about the different computer aided solutions they get familiar with and the technologies used in the companies they have get practice.

DISCUSSION AND CONCLUSION

The building industry is now on the threshold of adapting the actual concept of interoperability and slowly putting product models into use [11]. The users now can be described as early adopters and the majority of the industry (estimated at over 90 %) has not reacted yet. The architects are first in the chain as they are creating the initial model in the beginning of the design process. The future belongs to those who will start to use the 3D models as early as possible.

Contemporary CAAD solutions should be taught from the very beginning of architectural education parallel with the classical design methods. Gradually teaching as students design education advances seems to be better, because it is difficult to maintain the students' motivation in class by just practicing the tools and working with separate design examples.

The subject content should be reviewed and revised each year in order to up-date, improvise and keep the students up with new emerging trends in the fast changing IT word which applies to architectural design. Model-based architectural design concept and building design information sharing through the IFC standard should get wider acceptance in the university curricula.

The is a need to shift the thinking paradigm from one that is limited to understanding and acquiring practical today's knowledge towards the one that is more comprehensive in nature and supports hands-on-application as being practice in high tech countries outside the academic environment.

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