Applying a Digital Chain in Teaching CAAD and CAAM

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Abstract. *This paper describes a successful approach in teaching caad and the use of state-of-the art caad-technologies in postgraduate architectural education. Since it's first set up in the year 2002, variations of this curriculum were applied on an annual basis. Its main characteristic is the efficient transfer of knowledge and practical use of more than 10 central techniques in caad/caam (computer aided architectural manufacturing) within the tight period of 6 months. Recipients were international postgraduate students from the field of architecture and related disciplines. Their studies were a full-time course lasting 12 months with six months modular introduction and 6 months individual and group thesis works [1].*

Keywords. *Teaching, collaborative design, cnc production, mass customisation, education & practice, user participation, web-based design*

Figure 1. Final group thesis of nine postgraduate students at ETH Zurich. A pavilion-like physical object sized 3 by 3 by 3 meters is the output of the applied 'digital chain'.

Teaching CAAD/CAAM

A modular curricular structure was introduced for teaching single modules each focussing on a specific issue of computers within the architectural design and production. In particular theoretical, haptic and real-world issues were addressed. Each consequent module allowed to be connected to one of the previous modules. This finally defines the so-called 'digital chain'. This means the purely digital interconnection of data within architectural design and production. It describes as well the hypothetical lack of paper prints and human labour in production. The didactical interconnection of ten modules was introduced in order to give permanent psychological need for the students to intensively focus on a specific module rather then

block	duration (in weeks)	module	technology	level of complexity (A-E)	dependency to module	program-ming	theory	cnc-production
block1 - supported tools								
	1	1. warm-up	flash/actionscript	A		X		
	4	2. parametric CAD Scripting	vectorscript	A	1	X		
	3	3. historical analysis	flash	A	1		X	
	4	4. caam milling 'surface light'	maya/mel, cncmill	BB	1,2,3	X	X	X
block2 - digital interaction								
	2	5. database & e-shops	mySQL, Perl	CCC	1,2	X		
	4	6. configurator & e-shop	actionscript, Perl	CCC	1,2,5	X	X	
	4	7. caam 'sculpted surfaces'	vectorscript, cnc laser	CCC	1,2,3,4,6	X	X	X
block3 - artificially generated								
	3	8. objects oriented programming	squeak, java	DDDD	1,5,6	X		
	2	9. agent systems	squeak, java	DDDD	1,4,6,8	X	X	
	3	10. caam laser cutting	vectorscript, cnc laser	CCC	1,2,3,4,6,7,9	X	X	X
final thesis								
		11. final groupwork	all above + 3d-printer, mel	EEEEE	1 to 10	X	X	X
		and individual thesises		EEEEE	1 to 10			
		12. final exhibition & documentation	large scale printing			X	X	X

Table 1. Curriculum of post-graduate studies in CAAD at ETH Zurich. List of dependencies within the 'digital chain'.

waiting a couple of weeks and re-start with a new module.

The technologies that were taught are:
• web based architectural design,
• parameterised and generic design using standard CAAD-software,
• scripting,
• digital interactive documentation,
• object oriented programming and CNC-based rapid prototyping on various machines.

The time provided was six months, with an average duration of four weeks for each module. The software we used is mainly conventional in order to provide real world context:
• Nemetschek's Vectorworks and Alias' Maya for design, respectively their scripting extension as the focus is on parameterisation and generation;
• Macromedia Flash for interaction, e-commerce and online design software (configurators),
• mySQL and Perl for the internet based configurators and network applications;
• Sqeak/Smalltalk and Sun's Java for introduction into object oriented programming, self generated structures and agent systems

Concerning the physical set-up, small groups, permanent access to machines and extremely short introduction of new technologies were introduced. All student have personal workplaces and some computers provided by us over the whole time. The location is adjacent to the chair's own office. Due to the very brief introductions of only a few hours for each topic, auto didactical learning by the students and collaboration with other students was mandatory. Web based teaching allowed permanent supervision. In particular a web based editing system known as 'wikiwiki' for tutorials, exercises and submissions helped both students and teachers.

The introductions and specific help was given by specialized teachers. All of them are colleagues of the coordinator and teaching assistants at our Chair of CAAD. Therefore motivated people with multidisciplinary backgrounds such as architecture, art-history, computer science were teaching for roughly three to four weeks each. Main focus was on hands-on exercises (Dewey, 1916) – one every week - which were given out to be finished the speed for producing goal-oriented. The colleagues that were teaching sketched possible

ways for a solution of the exercise in order to show a solution. Two meetings a week in group brought immediate evaluation of the students well feeling, the level of work and eventual need for curricular corrections. Final presentations in group and partly with invited guests took place at the end of each module. All exercises were set up to have several fall-back scenarios if the intended level would not have been reached. All subsidiary scenarios would have allowed to keep the digital chain connected [Table 1].

It is known, that each of the didactical aspects described above are not new. But as far as we know their combination is new in teaching computer generated design and computer integrated production for students of architecture. Previous courses that introduced one single technology over one semester with permanent assistance resulted in less quality. Didactical methods that we used here are:

1. project oriented tuition,
2. situational referencing and
3. accompanying quality control through e-learning tools.

As described by B. Bloom (1956), the classification of knowledge into groups, subsets and orders played the central key in setting up the curriculum. The consecutive introduction of tutorials and applications for each new technology generated a deeper understanding. This is because discrete examinations of the topics were done by the students themselves. Self initiated collaborations helped towards a fast understanding and progress. A high level of didactical cognition (rational processed knowledge) was achieved as the students analysed and solved problems on their own. This means that a situational method was overlaid. It is indeed very much related to traditional work processes of architects. A direct link back to real world aspects appears at the end of the postgraduate course. This is when the group thesis was done by the students and multiple considerations of possibilities and limitations within each chain link have

to be respected (see as well RUEDENAUER).

A didactical method that we didn't used is pure memorising.

Results

The main innovations are:

• continuous didactical and technological interconnection of stand-alone technologies and methodologies.

• short teaching period of 6 months incl. 10 technologies.

• high success rate in knowledge transfer despite a short time.

• deep understanding of future possibilities within the architectural practise.

• generating specialized architects knowing the principles and applications of computer generated architecture and computer based production.

• highly motivated students

• excellence in work

The main goal of this course was to hand over a large amount of theoretical and practical knowledge within a short time. Although a wide spectrum of issues allow only a shallow intellectual depth within each specified topic, the high quality of the student work impressed. Topics chosen by the students were e.g. 'web-design tools with data base interaction', 'parametric shadow calculation software', 'geometrical spatial optimisation tool' and 'complex physical structures' as their individual thesis work. Complexity means e.g. geometrical and/or structural and spatial overlap of non-orthogonal wooden elements that could not be drawn and produced within weeks by hand, but within days by using the principles taught by the 'digital chain'. It has to be mentioned, that only 10% of the students ever looked at the HTML-source windows of web browsers before starting this postgraduate course and none did scripting before.

Another example of the 'power' initiated by the

curriculum are the impressive objects done within the so called group thesis. These are objects each 3 by 3 by 3 meters handling either 150 single CNC-cut elements or 9 bevelled and intersecting wooden planes. All physical structures were processed by means of mathematical calculation and a computer controlled production on ETH Zurich's own CNC machines. Self organising algorithms were applied in one of the projects as it underlines the complexity of the object and the successful teaching from 'zero' to 'object-oriented programming' in architecture. All work answers mainly geometrical, formal, structural, ecological, economical and process oriented questions. It was about the prospective architects to design algorithms and processes. Given the tools of the first six months in teaching, most graduates continue currently their research in the field of computer-generated, -produced or -integrated architecture. This on academic level, freelancing of as employees in renowned architecture offices.

The second result is the successful collaboration of different people, technologies, materials and machines within the 'digital chain'. Pedagogically the materialized manifestation in form of the huge structure, the group thesis works, was important for the students. It showed the power of creating a large object, which would not been possible to do by one person only or without one of the module taught before, nor without a certain technology [2].

The third result is the student's sound knowledge in the relatively new discipline of applied CAAM. This strengthens their position in a demanding real-world context. The skilled architect is able to keep parts of the whole CNC-construction process within his own office. Less external consultants will be needed and therefore the field of applications and potential source of income grows. This can be monitored by watching various professional architecture firms such as Asymptote, glform, gramaziokohler or KCAP (http://www.asymptote.net/, http://www.glform.com/, http://www.gramaziokohler.com, http://www.kcap.nl/ : May 2005).

Some of the student works were recently honoured with a prize for innovation at the Cologne furniture fair for the innovative approach in design and production.

Figure 2. Student works (from top left to bottom right): 3dprint of tetris structure (plaster), cnc-milled parametric chair (foam), projection of milled Kodak-slide (acryl), cnc-milled lamp-cover (plywood), cnc-lasered poem (acrylic), assembly of group these esg_PAV-pavilion. Autors: Becker, Fricker, Helm, Mehta, Mueller, Ruedenauer, Segerer, Schuerch, Wojcik.

Outlook

As computer integrated production attracts more importance within architecture worldwide, it is believed that fundamental steps can be achieved, if architects fulfil all mandatory consultations concerning computer based production on their own. Computer based design and production is therefore an integrated part of future buildings. The impact of computers is not necessarily ornamental, it is mainly structural. It is mainly the result of a process than of a certain style. In our education we will keep on emphasizing this process.

In a next step, the implementation of cross-disciplinary topics such as structural engineering and economical issues within the digital chain are intended. The research at our chair of CAAD so far succeded in connecing structural calculations, generic design and cnc-production (see SCHEURER).

Acknowledgement

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