Five Experiments to Elicit CAAD Work Strategies of Students in Three Levels of Education

Dana Matějovská [1], Henri Achten [2]
[1-2] Czech Technical University, Prague (Czech Republic)
http://ustavy.fa.cvut.cz/15116/
[1] matejdan@fa.cvut.cz, [2] achten@fa.cvut.cz

Abstract. *In order to understand the learning needs of our students, we have defined a series of five small experiments. In each experiment, a subject has to perform a limited task using a CAD system. The experiments are undertaken by subjects from three different groups: pre-university school goers, first year students of architecture, and advanced students of architecture. By comparing the differences between the groups we can identify the following aspects: (1) start level of students, (2) starting work strategies, (3) development of work strategies, and (4) deficiences in work strategies. On this basis, we can develop more specific teaching material that will be better suited to the needs of the students. In this paper we report on the experimental setup, research methodology, and preliminary results.*
Keywords: *Learning strategies, experimental research.*

Introduction

The main aim of our work is to understand which are the best pedagogical approaches to teach students computer aided architectural design. This understanding has three main aspects. The first aspect concerns the working strategies that novice users apply when working with CAAD. We need to understand the 'base-state' of students so that we get an idea of basic skills, competences, and working methods. The second aspect concerns the pedagogical strategies that are available for teaching CAAD. This informs our range of possibilities for teaching CAAD. The third aspect concerns ways to gain reliable insight in the learning progress of students. This insight is important for monitoring the effectiveness of our attempts. In this paper, we focus mainly on the first and third questions (working strategies and measurement).

General skills of designers and design students have been studied early on (see for example Cross 1990 and Lawson 1990). Work on learning styles and design performance has been investigated by Demirbas and Demirkan (2003) and Kvan and Yunyan (2005). Angulo (2006) compared the learning outcome of students using E-learning tutorials. Kvan and Song (2005) investigated at the meta-level of learning loops the performance of students in particular in collaborative teams.

There is a large amount of experimental work with CAAD in education (which can be easily checked in the eCAADe proceedings – compare for example work on parametric modelling by Bechthold (2007), Serrato-Combe's (2007) exploration of animation, or modelling emotions with CAAD by Koszewski and Wrona (2007)). To the best of our knowledge, however, there has not been much research on the working strategies of students in combination with their usage of CAAD software. Currently we can observe that CAAD education implicitly acknowledges two tracks of education: learning how to design, and learning how to work with CAAD. This rather orthodox view of design can be challenged from two sides: (a) accomplished architectural design students still have problems when they start with CAAD, and (b) working with CAAD is not an add-on to designing, it is designing itself.

Even when we accept the orthodox view, we can see that designing with CAAD requires different strategies and work processes. Students typically have less developed skills to use CAAD than they have skills for sketching and scale modelling (the other preferred media for design), and CAAD software always requires a higher degree of specification and deliberation in their use. In particular, CAAD software requires a much clearer understanding of descriptive geometry to make things work well. Additionally, one needs to understand the build up and underlying structures of objects in CAAD software to translate from geometric understanding to what is possible or how things are done in CAAD. Based on these considerations we pose that we need a better understanding how CAAD-learning takes place. Earlier, we have investigated CAAD skills of students through enquiries (Matějovská and Achten 2007). In this research, we continue by investigating the differences in CAAD strategies of students.

Research methodology

We used protocol analysis (Ericsson and Simon 1993) applied to limited tasks as main research method (as shown for example in Kruger and Cross 2006). In order to elicit the CAAD work strategies of students, we have designed five small experiments. The experiments vary in degree of complexity and degree of freedom allowed to the subjects to come up with an answer. The first three experiments are of the 'follow-by-example' type, and the last two experiments are more open-ended creative tasks.

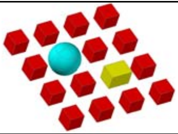
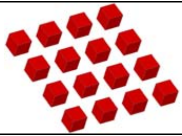
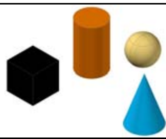
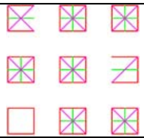
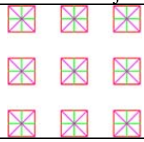
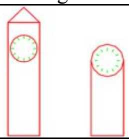
The experiments are conducted on three groups of subjects, each of which are in a different level of education: pre-university school goers of a grammar school (group A – 'beginner'), first year architecture bachelor students (group B – 'informed'), and master students (group C – 'advanced'). In this way we gain understanding in 'CAAD-logic' for different levels of subjects (see Table 1).

Experiments are executed individually. We have set up a test system in a separate room, which allows

Group	Age	School	Computer experience
A beginners, 5 subjects	17-23	Gymnasium; applicant of our university; one from other university (UK).	Internet, graphics software (Adobe, Corel draw), Microsoft Office, games.
B informed, 6 subjects	19-20	FA ČVUT 1st year.	Basic knowledge (Internet, Microsoft Office, Adobe, Corel draw), AutoCAD.
C advanced, 5 subjects	21-26	FA ČVUT 2nd , 4th, and 6th year.	As group B and also 3D Studio Max. Some subjects: Rhino, ArchiCad, SketchUp, Flash, etc.

Table 1
Subjects that participated in the experiment.

Table 2
The five tasks of the experiments.

Task No.	Start	End
1		
	Task text: Change the drawing, result is to have the same 16 cubes in the grid. **Research expectation**: subjects have to learn how to orientate in 3D space; the erase command will be used; objects will be copied with osnap (object snap).	
2		
	Task text: Use some of these elements (cube, cylinder, sphere, cone) and arrange them into the letter "T" in 3D space. **Research expectation**: subjects will work in 3D space; they will use osnap (centre for sphere and circle) and orthogonal directions for moving the objects; use change of view – rotation in the plane – and change the position of objects with move.	
3		
	Task text: Change the file such that the result will be the picture of the same 9 elements in 2D. **Research expectation**: subjects create array with one correct element.	
4		
	Task text: Draw the shapes of the cone in 2D. The base is a square (100x100mm), the height of the cone depends on you. **Research expectation**: subjects will use rectangle and polygon (triangle) command; there are many possibilities how to construct the triangles.	
5	No start file provided.	
	Task text: Draw a clock tower in 2D, creative task. **Research expectation**: subjects will create symmetrical designs; they will explore different shapes for the clock; use array to create the ticks for time.	

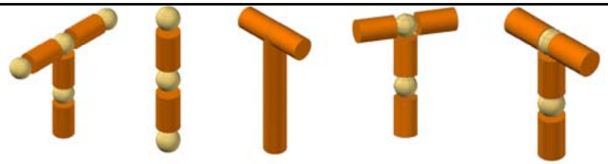
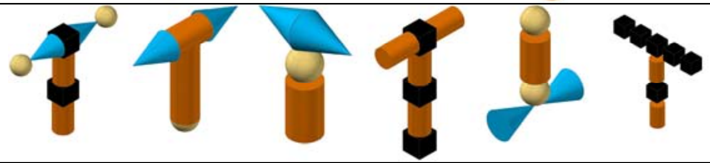
A	
B	
C	

Table 3
Results of task 2.

the subject to work undisturbed. There is no time limit for each task – the experiment ends when the achieved task has been accomplished. At the start, the subject gets an introduction to the system: how to use the computer, and how to start and end the recording of the sessions.

For each experiment the subject gets a paper which shows the end condition of the test and information about the task. No other information is provided. All actions by the subject are recorded by the computer. Additionally, the subject is required to talk in a microphone about his or her intentions. Also, if the subject has a question, (s)he has to ask it explicitly (so it will be recorded) – in this way we can capture the problem. We found that group A required continuous support, whereas subjects from group B and C could work autonomously on the tasks.

After each task, the subject is required to save the result and continue with the next task. There is no consultation between tasks; the whole session ends when the last task has been completed. The protocols consist of a computer file that contains all actions taken with the computer, and a separate audio-file of the speak-aloud part.

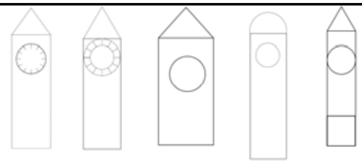
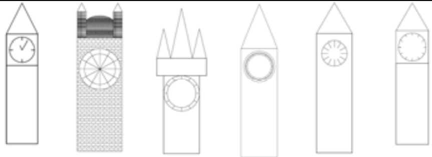
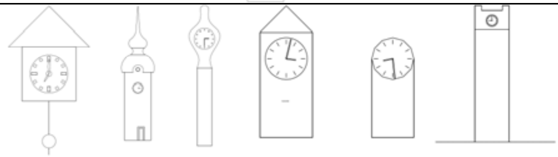
After the experiments, each individual protocol was analysed. We took particular notice of the work methods (order of commands used by the subjects) and errors (mistaken use of commands, wrong input, deviance from desired end result) and problems subjects encountered with the program (fixation, turning in circles, trying to find commands).

Technical setup of experiments

In all experiments we use AutoCAD 2008, mainly because of availability and AutoCAD being representative for a mainstream CAD system. The experiments are executed on a standard PC workstation. The subjects use a mouse for command input and manipulation. Next to them the microphone is mounted.

In each experiment, we observe the choice of commands, as well as the sequence in which the commands are used and the specific settings or parameters that are applied. This is recorded with the screen capture software HyperCam. HyperCam records all actions performed by the user on the

Table 4
Results of task 5.

A	
B	
C	

computer, such as movement of the mouse, selection of commands, operations on objects, and how everything appears on the workdesk of the software. For the analysis part, HyperCam allows playback of the recorded session. We require subjects to speak aloud during the experiment, and record the comments by the subjects; for this we also used HyperCam. After the experiments, we found out that the sound-files were unusable, so that the audio part of the protocols could not be used in the analysis.

Since there was no time limit for the tasks, the resulting size of the protocols varied considerably: the HyperCam software made the audio files , they varied between 4 and 373 GB (only one accident was 447 GB). All protocols were stored on the experimental computer and backup DVD's.

Tasks

The tasks are very limited exercises, in which subjects are provided with a start file and an example of the end result. They are required to reproduce the end result by means of AutoCAD. Table 2 summarises the tasks.

Preliminary results

Given the low number of subjects participating in the experiments, it is not possible to derive robust findings yet, but we will make quantitative analysis and report on the research methodology, experiments, and preliminary results. Table 3 and 4 summarise the results by the subjects of tasks 2 and 5 (since the goal of tasks 1, 3, and 4 is simply to reproduce the end example, we do not include them here).

Observations

Based on the protocols and experiences during the experiments, we were able to observe the kind of problems subjects encountered in the tasks (see Table 5).

Each group of subjects encountered specific problems concerning the use of CAAD. In Table 6 we summarise our observations about each group.

Group	Task	Work method and observed problems
A – beginners (31-55 minutes, average 47 minutes)	1	How to work with the mouse; watching the command line interaction; apply a different way of thinking about the solution (more technical).
	2	The subjects worked in complete random fashion, trying out different commands and manipulations of the objects without clear goal direction. They restricted themselves to the sphere and cylinder shown in the example result.
	3	There were no observable problems; subjects seemed to have benefited from doing task 1 earlier; subjects only copied separate lines, not sets of lines.
	4	Subjects created the triangles through classical scribing process with circles and creating step by step the triangles (as they are taught in school).
	5	Subjects created solutions very similar to the example result, without any details. In the case that they added ticks of the clock, they only drew 1 tick (the results shown above are after instruction how to use array).
B – informed (22-50 minutes, average 34 minutes)	1	Overview of the program was missing; the subjects worked ad hoc and responded to incidents.
	2	The subjects experimented with all available objects, rather than limiting themselves to the sphere and cylinder of the example.
	3	The subjects worked on the line level of the images, responding to missing lines. They did not recognise the opportunity offered by array. They used layers to set the colour of the lines.
	4	The square was created by lines (not rectangle command), and the multiple triangles were created with the mirror command.
	5	The subjects limited themselves to straight lines and circles, using symmetrical arrangements. To create the ticks, some students used random angle to approximate the proper orientation.
C - advanced (17-51 minutes, average 30 minutes)	1	The subjects grasped the possibility of quickly replacing the sphere and cube in one command by selecting 2 cubes in the same operation.
	2	The subjects quickly reproduced the end result without deviating by using other objects and/or arrangements.
	3	Subjects worked on the grouped objects rather than the line level, but they missed to notice that some elements were grouped and others separate entities.
	4	The square was created with rectangle command, and the multiple triangles were created with the mirror command.
	5	The subjects used rectangles and had variations on the roof elements; they used array to create the proper ticks of the clock.

Table 5
Work method and observed problems in the tasks of the experiment.

Table 6
Problems and observations for each of the groups and tasks of the experiments.

Group	Observations
A – beginners	There was a lot of trial-and-error while the subjects were acquanting themselves with the program.
	The subjects had to get used to a different use of the mouse, including how to use the click function.
	The subjects had problems understanding the role of the command line information; this concerns the user-program communication.
	The subjects had difficulty understanding and manipulating the views in 3D, but they became used to it very quickly.
	Some subjects had a background in comprehensive school, not a technical school, so they had some difficulty in technical thinking about the task; nevertheless, they were able to complete the task.
B - informed	There was a lot of trial-and-error since the subjects were not very skilled.
	The subjects did not require instruction about the 3D use of the commands.
	The subjects mainly used copy; sometimes they drew new lines, and in some cases they drew helping lines.
	The subjects use simple commands (copy, draw line, erase) in a very fast manner, but they do not apply more complex commands (selection groups, array) that require more strategic understanding.
C - advanced	The subjects had a good overview of the implications of the task, and they were skilled in the required commands.
	The subjects worked efficiently and fast, but did not deviate from the example result.
	Some subjects had completely forgotten the more complicated commands (such as array), but after some searching were able to find them quickly.
	Task 5 was the only task that prompted the subjects to create highly varied solutions; somehow it stimulated their sense to be individual.

Conclusions

Since the amount of subjects in the experiment was quite small, we cannot derive statistically solid conclusions. We now have experience with both the set-up of the experiment and the problems that subjects faced with each task of the experiment.

Research method

We have just started with this research method and set of questions, and have presented in this paper the preliminary results. In the first place, we want to increase the number of subjects in the current experiments to acquire more reliable statistical data.

We have noticed a dependency effect between tasks 1 and 3, which diminishes the measurement effectiveness of the commands that are used. It shifts the focus from acquaintance of the commands to the way the commands are used.

Some subjects of group A were from comprehensive schools rather than technical or art schools. In particular in task 4 this turned out to be a marked disadvantage to solve the task. Since these subjects are less likely to apply for study at the Faculty, we probably need to be more selective in the subjects for group A.

In our view, this method allows for a wider range of pedagogical questions to be studied in a quantitative and qualitative way. Therefore in the future, we want to expand the research questions about CAAD learning by architectural students.

Differences between groups

Although all subjects of group A had experience with the use of computers (see Table 1), CAAD software is a completely different class of programs that they need to get used to. This starts at the level of the User Interface up to the specific commands and a technical way of thinking about the solution of the tasks. Notwithstanding this rather high threshold, we noticed that all subjects were able to enter the use of the software and start working in the relative short amount of time available in the tasks of the experiment. The students of group B were very skilled in using simple command that act on single entities, but they clearly have not formed more strategic insight how to use larger sets of entities, or how to apply more complex commands that use more transformations. The students of group C had developed more integrated strategies and were able to quickly and efficiently perform the requested tasks. Nevertheless, we also noticed that they regularly had to search for commands and think about their strategy, which seems to be in contradiction to their self-estimated level of skills (they seem to overestimate themselves).

Preliminary recommendations for CAAD teaching

Based on our experiences, we can formulate the following preliminary recommendations for CAAD teaching; these are highly tentative given the small amount of subjects that participated in the experiments:

a. in addition to CAAD techniques, we also need to define basic skills and information about how to design; CAAD is not just a collection of techniques, but it is design.
b. we have to develop ways how to stimulate students that they search for multiple ways how to solve a given problem; students now seem fixed to single solution strategies and miss opportunities to benefit from specific properties of CAAD.
c. getting to learn software through tasks (implicit learning; learning by doing) seems more productive than command oriented teaching (explicit learning).
d. the main goal of education should focus on the core issues of a software and teach the students an attitude of exploration through which they can find the more detailed aspects themselves.

Acknowledgements

We would like to thank the subjects who took part in the experiment for their participation.

References

Angulo, A.: 2006, Optimization in the balance between the production effort of E-learning tutorials and their related learning outcome, in Proceedings of the 10th Iberoamerican Congress of Digital Graphics, Santiago de Chile, pp. 122-126.

Bechthold, M.: 2007, Teaching technology: CAD/CAM, parametric design and interactivity, in J. Kieferle and K. Ehler (eds.), Predicting the future – Proceedings of the 25th International eCAADe Conference, Frankfurt, pp. 767-775.

Cross, N.: 1990, The nature and nurture of design ability, Design Studies, 11(3), pp. 127-140.

Demirbas, O. O. and Demirkan, H.: 2003, Focus on architectural design process through learning styles. Design Studies, 24(5), pp. 437-456.

Ericsson, K. A. and Simon, H. A.: 1993, Protocol analysis: verbal reports as data, MIT Press, Cambridge.

Koszewski, K. and Wrona, S.: 2007, Me, Architect, in J. Kieferle and K. Ehlers (eds.), Predicting the future – Proceedings of the 25th eCAADe conference, Frankfurt, pp. 415-422.

Kruger, C. and Cross, N.: 2006, Solution driven versus problem driven design: strategies and outcomes. Design Studies, 27(5), pp. 527-548.

Kvan, T. and Song, G.: 2005, Examining learning in multiple settings – Using a Linkograph to examine design learning, in B. Martens and A. Brown (eds.), Proceedings of the 11th International Conference on Computer Aided Architectural Design Futures, Springer, Dordrecht, pp. 311-320.

Kvan, T. and Yunyan, J.: 2005, Students' learning styles and their correlation with performance in architectural design studio, Design Studies, 26(1), pp. 19-34.

Lawson, B.: 1990, How designers think – The design process demystified, Butterworth Architecture, London.

Matějovská, D. and Achten, H. H.: 2007, CAAD restarted – Some experiences in improvement of CAAD education, in J. Kieferle and K. Ehlers (eds.), Predicting the future – Proceedings of the 25th eCAADe conference, Frankfurt, pp. 409-414.

Serrato-Combe, A.: 2007, SAFDE – Sadness, Anger, Fear, Disgust, Enjoyment, in J. Kieferle and K. Ehlers (eds.), Predicting the future – Proceedings of the 25th International eCAADe Conference, Frankfurt, pp. 237-243.