INTERNATIONAL DESIGN CONFERENCE - DESIGN 2002
Dubrovnik, May 14 - 17, 2002.

LEARNING PROCESSES IN GROUP DESIGNING

M.W. Ertsen

Keywords: design process, student teams, experiential learning

1. Introduction

Learning to design in teams is an important activity of the civil engineering program at Delft University of Technology, the Netherlands. Civil Engineering Project Education organizes about 125 projects each year, which are carried out by groups of students. Project groups analyze a problem and design a solution. During the project aspects like function, shape, layout and (environmental) effects have to be taken into account, as in real practice. Depending on the year in which the project is scheduled, the accent is put upon spatial or constructive elaborations of the subject. Students are supposed to apply the knowledge and skills they learned in other courses. The design projects offer a structured approach to a design problem, similar to the "external ritual of design" described by Radcliffe [1995] and employed in some or another form used in many design disciplines: clarify and quantify the problem, generate concepts, refine and evaluate them, design in detail, test a prototype, revise it and present it.

In the learning process of student teams leading to a design, three dimensions play a role [Cross and Clayburn Cross 1995]. First, design teams follow a sequence of activities based on a rationalized approach to the problem: the process dimension. Second, design teams have to employ skills and knowledge to solve the problem: the cognitive dimension. Third, within the design team, designers interact with each other, and the team usually interacts with others too, such as clients or colleagues: the social dimension [see also Brereton et al 1995]. This paper discusses results from a small research project, which studied the ways the activities of civil engineering student design teams could be understood with these dimensions in mind.

2. Professional practice and team learning

Teamwork has become of considerable importance in normal professional design activity. Approaches like Simultaneous (Concurrent) Engineering depend to a large extent on teams of co-operating designers. SE originally developed in manufacturing industries like the automotive industry, but is increasingly employed in fields like chemical and civil engineering. SE aims to avoid as much as possible to adapt designs in later stages of the design process, as making changes in this stage is much more costly. At the same time the danger of making mistakes in an earlier stage should be avoided. This is done by bringing the expertise that is traditionally used in later stages (like servicing, sales, component supply) into early stages of the process [Ertsen 1999, Ertsen et al 1999].

Simultaneous engineering design approaches employ the abilities of different designing engineers involved to share their experience with others and learn from each other during design practice. In such a process of experiential learning, Kolb [1984] (figure 1) distinguishes two dimensions in which learning processes can vary between two poles: concrete-abstract and active-passive. On the basis of these dimensions he defines four possible learning moments in a cyclical learning model. All four dimensions are entries for learning, but Kolb prefers immediate concrete experience as the basis for observation and reflection. Observations are used for the construction of theories that guide for new active experimentation. The four entries become phases in a learning cycle, moments of certain learning activities in a cyclical learning process. A concrete problem is the starting point: the designer (individual or group) experiences the problem. The next stage in the process is to try to understand the problem, to place the problem in its context. The mobilization of available (theoretical) knowledge is crucial at this stage. It is crucial too not to reduce the problem too fast, as this moment offers the opportunity to look at relevant contextual issues. In the stage of abstract conceptualization the designer has to link the concrete problem and abstract concepts. More knowledge is mobilized, discovered and evaluated. Preliminary solutions are formulated. These solutions (hypotheses) are tested in the stage of experimentation, which can take place in engineering practices and educational settings (design courses), and results in new experiences. The learning designer is ready to start a new learning cycle.

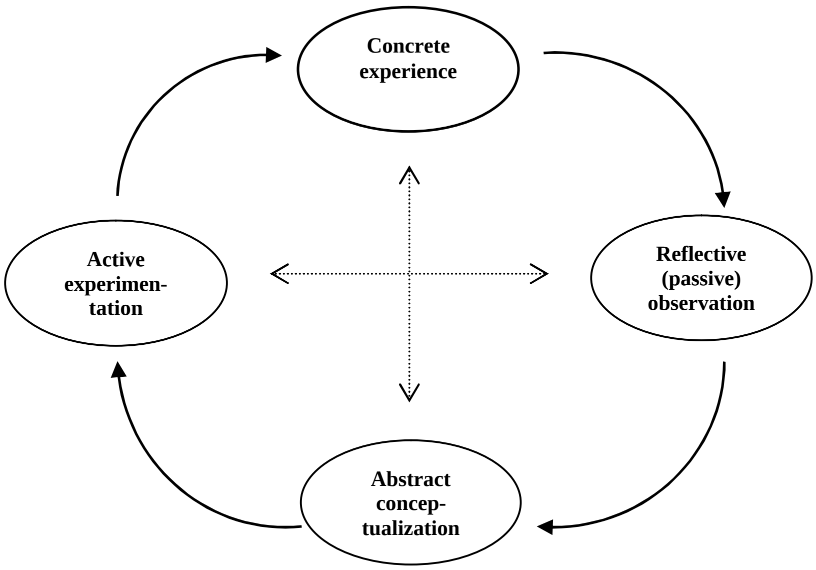

Figure 1. Experiential learning cycle

3. Civil engineering team design

In general, learning results of the civil engineering design projects so far (which have been organised for more than 25 years already) have been reasonably satisfying. Two main concerns, however, have been identified more than once, and were the stimulus to re-organise the design projects this year. A first concern was the difference in learning environment between projects and other courses [Ertsen 2001]. Courses are relatively closed environments, with highly structured contents and very few open-ended questions. Projects use open-ended problems by definition. For many students, the step from a closed environment to an open one, in which they have to apply knowledge they learned in another context themselves, appears to be very difficult.

A second main concern, however, is the focus of this paper. Experiences with the design projects made clear that learning problem-solving skills and a well-defined design approach are not sufficient for individuals to become successful designers, nor guarantee that they could tackle problems of all sorts. Austin et al [2001] found no evidence to suggest that following a design process, be it in an iterative or systematic manner, will help teams to generate better design concepts or reduce the time period spent reaching that concept. The best design in their experiment was made by the team that did not apply a systematic approach. Their success seemed to be that they had a wide knowledge base, but also that the team members were willing to listen to one another [Austin et al 2001]. The cognitive and social dimensions of team design appeared to be much more important than the process dimension. This is confirmed by Norman [1988], who found that processes of problem solving in general have some very un-skill-like characteristics [Norman 1988]. A group of students studied by Norman, from the first year of medical school, used exactly the same problem-solving process as experts. The main difference between expert clinicians and students, however, was that experts generate better hypotheses, which is not a characteristic of a skill. The correctness of specific hypotheses, rather than

process variables, was the strongest predictor of success. The expert is an expert because he/she has extensive *experience*, and can apply his/her knowledge and skills to the solution of problems.
Building an integrated knowledge base, which can be fruitfully employed in designing and/or problem solving is a major goal of education. Amongst the educational approaches which explicitly employ this idea are Problem or Project Based Learning models, in which students learn the prerequisite knowledge and skills in the context of a problem relevant for the future profession of students. It enables students to gain expert-like experience during their study. With only some isolated projects (as in the Delft civil engineering program) the effectiveness of learning remains low, as the learning environments of projects and the majority of the curriculum are too different. A study program based on project learning, like in the engineering programs in Aalborg University (Denmark), appears to be more fruitful [Ertsen 2000].

3.1 The research project

With civil engineering experience confirmed by results discussed in the literature on design and education, there was a basis to rethink the educational set-up of the design projects in the curriculum. During the discussions within the department on the design projects, it became clear that, despite the many evaluations that were available (providing useful information), insight in the activities within the teams themselves was lacking. All information available was the result of looking backwards: tutors wrote down their findings on the results of the teams, students filled in evaluation forms. What was lacking was information directly based on the design and learning processes occurring in the teams. In the situation as described, in which restructuring of the projects was debated upon, the need for such information was felt. The resulting small pilot research project, from which some results are presented in this paper, is a first step to a larger research program, which has to focus on four issues: (1) (experiential) learning in groups; (2) the role of a design methodology in team design processes; (3) differences between design approaches and results of novice and expert designers; and (4) learning processes of individual students. The pilot research focused on the first two issues. Four teams of five graduate civil engineering students were involved. Two observers per team documented activities, resulting in detailed descriptions of working processes. Documents produced by the groups, no matter how obscure, were gathered. Two teams worked on a small problem during 30 minutes. The focus of these sessions was on communication between team members. The discussion in this paper is based on two other sessions, during which two teams worked on a larger problem for 90 minutes (figure 2).

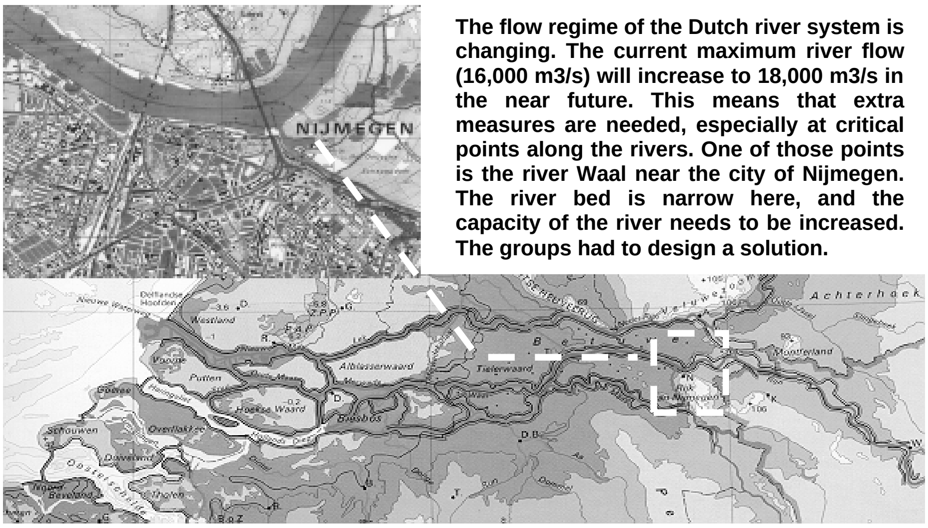

Figure 2. Design problem

4. Design activities of civil engineering student design teams

The design problem of figure 2 presents itself in an ill-structured way; it is not directly transferable into technical engineering concepts. The discharge problems of the river near Nijmegen could, for example, be a problem related to the hydraulic structures used, it could be an economic question, or a matter of political unrest. Most probably, many factors will be related. Therefore, analysing and understanding the problem is an important part of the design process. Furthermore, a team has to reach some shared or commonly held understanding of the problem [Cross and Clayburn Cross 1995]. Dwarakanath and Blessing [1995] found, that a group spends more time to analyse, structure and internalise their work than an individual, as designers in a group discuss with each other about it and have to explain to each other aspects regularly during the process, like the reasons why one alternative is better than another.

4.1 General design process

Generally, a team design process passes at the least three stages: (1) the starting phase (clarification of the problem), (2) concept design, (3) evaluation of concepts. If time and/or task permit, other phases, like making a detailed design, are added. Reaching a common understanding as a separate activity can be observed in both teams (figure 3), although team 1 takes more time than team 2. Team 1 is much more involved in framing the work of the team into a clear strategy, which is illustrated by the many process-directed remarks that team-members make during the process, like 'Should we write this down?' and 'What is the goal exactly?'. Team 2 moves more quickly to possible design concepts.

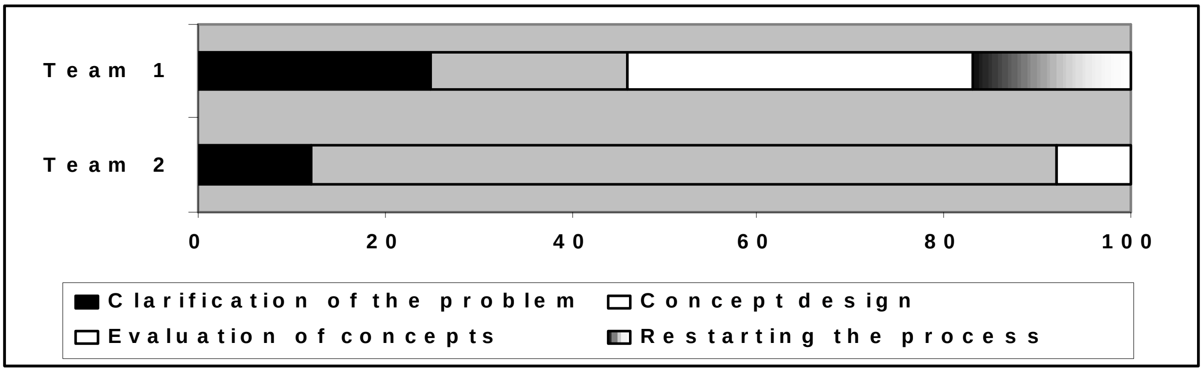

Figure 3. Relative time spent per phase in the design process (%)

Team 2 also works much longer and in much more detail on defining and designing concepts. This is not only illustrated in the percentage of time devoted to the activity, but also in the amount of documents produced during the process. Team 2 produced seven pages of requirements, drawings and calculations, where team 1 only produced one page. Team 2 was able to work out initial concepts into more detailed versions, whereas team 1 did not come further than stating general ideas. This became very clear when team 1 wanted to evaluate the concept designs discussed so far: it appeared to be impossible for the team members to reach agreement, due to a lack of clear understanding of both the concepts and the criteria. Remarks like 'I think you are just opposed to this concept' and 'What do we mean with this?' are illustrative. Team 2, although working much less structured, comes up with detailed design concepts, and is able to judge their applicability in the given situation quickly. Formulating and evaluating concepts were closely connected and not separable in time.

As a result of the problems team 1 encountered in their third phase, the team-members restarted the discussion on the problem. For example, during initial discussions the team concluded (correctly) that the river bed near Nijmegen is assymetrical, which has a large influence on the possibilities for solutions. In the fourth phase, this conclusion was questioned again. Team members felt lost, resulting in remarks like 'What do we have to do now?' and 'I don't understand it'. Although the difficulties of team 1 to come up with a acceptable design culminated in the second half of their working process, throughout the entire process it became clear that team-members felt uncomfortable. Remarks like 'I want coffee' are made a few times, and team-members snigger a lot, especially at moments when decisions have to be taken. Team 2, although team-members appear to deal with issues in an ad hoc manner, manages to keep the activities and members together. This is largely done through an informal division of tasks; team 2 never discussed any division of tasks during the process, but the observation results clearly show, that one of the members acts as the organiser, while others provide specific inputs.

4.2 Team self-assessment

After the 90 minutes of their design activities, the team-members were asked to evaluate their efforts, by giving their agreement on a list of statements in four categories: (1) personal experience; (2) team work; project approach; and (4) task satisfaction. Figure 4 gives the team scores for the four categories. Members of both teams state that they bring enough personal experience to the group to perform well. Members of both teams also agree that their respective teams worked well together. The category on project approach, which includes issues like whether the team used a systematic design approach or the efficiency of the team work, gives similar results for both teams. If we look at figure 5, which lists the different sub-categories of the general category 'project approach', a more accurate picture emerges.

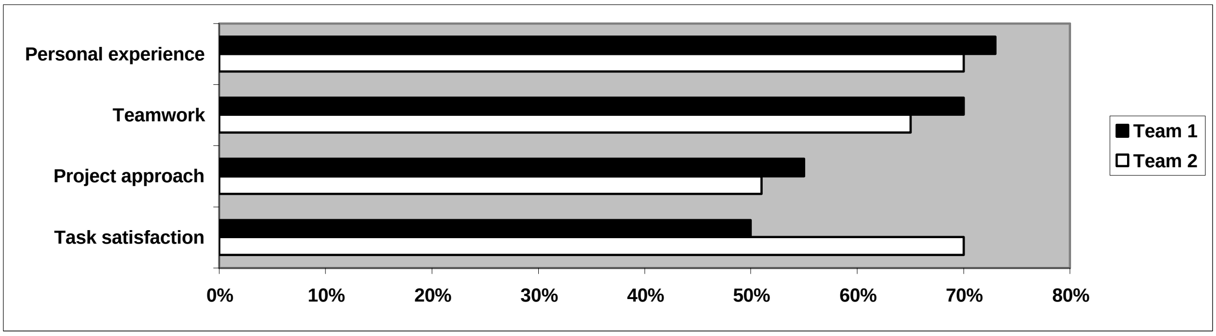

Figure 4. General team scores (% of total potential agreement)

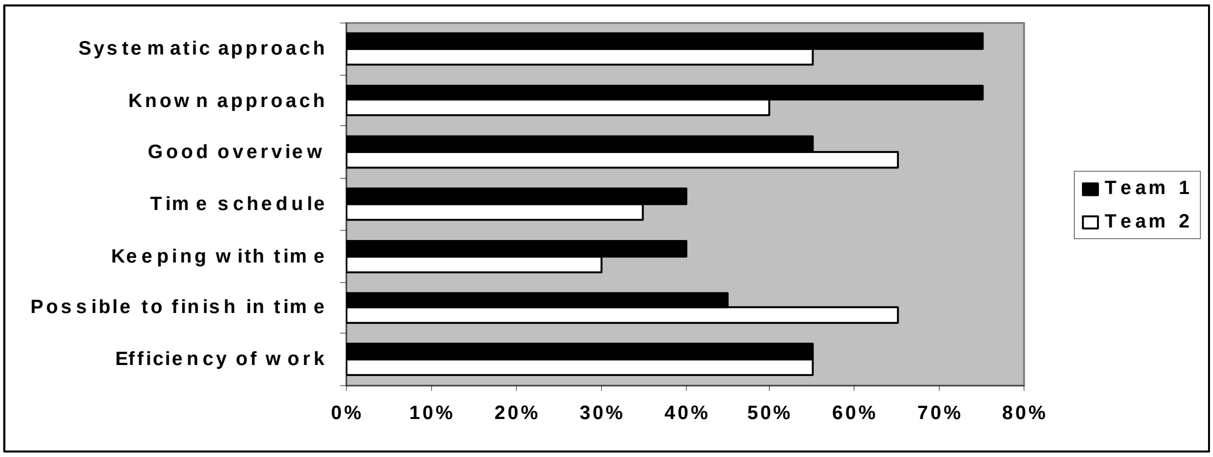

Figure 5. Team scores for Project Approach (% of potential total agreement)

Team 1 acknowledges what was already found from the observations: the team used a systematic approach, which they knew from other projects they had done. Other process-related categories like keeping with the time, scored higher with team 1 as well. Members of team 1 were less positive about two other issues, however. First, they thought that finishing the task within 90 minutes was difficult. Second, they scored slightly less on having an overview of the teams' efforts during the process.

5. Conclusive remarks

The results of this small research, which obviously cannot give more than suggestions for further study, are in agreement with the discussion in paragraph 2. The results suggest that the team that followed a clear sequence of activities based on a rationalized process approach (the first dimension mentioned in the introduction) did not come up with the best results. Team 1 was not able to employ their skills and knowledge to work on the problem in a satisfactory way, or in other words, to develop the cognitive dimension. This is illustrated too by the satisfaction of the teams themselves: team 1 is much less satisfied with the design task then team 2 (figure 4). The social dimension of interaction within the design teams appears to be valued independent from the other two dimensions: both teams, whatever difference might be found on result or process, evaluate their team performance as positive.

Acknowledgement

The author thanks the student-assistents who observed the design teams and the students of the design teams who were willing to share their team design session with the research team.

References

Austin, S., Steele, J., MacMillan, S., Kirby, P. and Spence, R., "Mapping the conceptual design activity of interdisciplinary teams", Design Studies, Vol.22, No.3, 2001, pp 211-232

Brereton M.F., Cannon D.M., Mabogunje A. and Leifer L.J., "Collaboration in design teams: how social interaction shapes the product", Analysing design activity, Cross N., Christiaans H. and Dorst K., John Wiley & Sons, Chichester, 1995, pp 319-341

Cross, N. and Clayburn Cross, A., "Observations of teamwork and social processes in design", Design Studies, Vol.16, No.2, 1995, pp 143-170

Dwarakanath S. and Blessing L., "Ingredients of the design process: a comparison between group and individual work", Analysing design activity, Cross N., Christiaans H. and Dorst K., John Wiley & Sons, Chichester, 1995, pp 93-116

Ertsen, M.W., 2000, "Integrated learning in engineering studies. The potential role of project education", Sixth Interamerican Conference on Engineering and Technology Education, Cincinatti, Ohio, USA, 2000, no pp

Ertsen, M.W., 1999, "The technical and the social in engineering education. Design and the social sciences. Making connections", University of Alberta, Edmonton, Canada, 1999, no pp

Ertsen, M.W., Ravesteijn, W. and De Graaff, E., "Bridging the gap between societal problems and engineering design." SEFI annual conference proceedings Engineering education: rediscovering the center, European Society for Engineering Education, Switserland, 1999, pp 181-186

Kolb D.A. "Experiential learning. Experience as the source of learning and development." Prentice Hall, New Jersey, 1984

Norman, G.R., "Problem-solving skills, solving problems and problem-based learning." Medical Education, Vol. 22, 1988, pp 279-286.

Radcliffe, D.F., "Concurrency of actions, ideas and knowledge displays within a design team", Analysing design activity, Cross N., Christiaans H. and Dorst K., John Wiley & Sons, Chichester, 1995, pp 343-364

Ir. Maurits W. Ertsen (MSc)
Delft University of Technology, Department of Civil Engineering and Geosciences
P.O. Box 5048, 2600 GA Delft, the Netherlands
Tel.: + 31 (0)15 278 4909/5284, +31 (0)15 278 5559
Email: m.ertsen@citg.tudelft.nl