CONCURRENT ENGINEERING IN EDUCATIONAL PROJECTS: CASE STUDY SVARTÖBERGET

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ABSTRACT

Each year, Luleå University of Technology teach 40 civil engineering students and 45 architectural engineering students basic knowledge in the construction process through a simulated real-life situation. In the third year, the grand total of 85 students is brought together and taught their respective professional roles through acting as experts within 6 different fields in the realization of a residential area. Research in the last decades has identified concurrent engineering as a possible method for streamlining the design phase in the construction process. The student project was therefore planned with a concurrent engineering approach, where all student groups start their work at the same time. The pedagogy was to teach students a new approach to working in large projects, with the side effect of testing if concurrent engineering is feasible also in educational projects.

Information is shared between groups through live documents on a project portal. Project coordination and communication is handled by 21 project leaders who meet regularly to exchange information between groups and detect missing information needed from other groups. Project planning is made through a method adopted from lean construction; Look Ahead Planning, which is part of the Last Planner method. IT-support is used to produce data and perform calculations but also as a tool for quality assurance across groups. All data is eventually summed up and presented in a virtual reality model of the new residential area. The VR model is gradually refined and the structure for delivering information into the model is drawn up by 6 appointed IT coordinators.

KEYWORDS

concurrent engineering, construction process, under-graduate education, last planner method

1. INTRODUCTION

The construction process can be characterized through many different aspects such as; lack of common goals, lack of coordination and poor quality management (Lagerqvist 2004). The traditional sequential process in construction, where long time and lack of communication limits the quality of the outcome (Kamara et al.1997), can be replaced by parallel processes using a Concurrent Engineering (CE) approach. CE is an approach to construction that will give higher quality and reduce process time for product development (Prasad 1996).

The competence of future engineers, working in the area of urban planning, architectural and civil engineering, will adopt and develop new technologies within construction. Working in a project based environment requires knowledge not just in the technical specialisation (Barkley et al., 2005). Construction also involves collaboration with other actors with different tasks, information sharing and commission performance (Nordstrand 2000). Collaboration in the Architecture, Engineering and Construction (AEC) industry has been supported by ICT tools for a more integrated process in the early planning and design for about twenty years (Forgber 1999). The AEC industry has only slowly adopted integration technology, but is still far behind the manufacturing industry (Sandberg et al. 2008). It is of importance that the current state in construction is changed to increase the effectiveness of the construction processes. One important ingredient is to educate future engineers in collaborating with other disciplines already during their training.

Figure 1: Luleå inner town with Svartöberget on the far right (Luleå model).

The aim of this paper is to investigate if concurrent engineering is useful in construction engineering education and training. Because of an absence of collaborative learning in undergraduate education for engineers, a project course was developed as a complement to the more traditional education for civil and architectural engineers at Luleå University of Technology. CE, as an approach to the construction process in the course, was implemented with support systems for information sharing, coordination for group processes with internet portals and planning tools. VR models and CAD structure as a mutual platform for buildings, infrastructure and technical solutions from each technical specialisation were used as quality control through the whole course (see figure 1). This paper presents a case study, where the course is described and evaluated.

2. THEORY

Pedagogical bases

Collaborative learning in the zone of proximal development

Collaborative learning in practice is when students in groups strive to reach learning goals. Contents in a project course are based on collaborative learning where participants have to be engaged to work together to reach the goal (Barkley et al. 2005). Working with collaborative learning is a suitable method for older students who can develop into autonomous, articulate, thinking people (Bruffe 1995). The Svartöberget project course had as a goal to support students in collaborative learning and is given to students in year 3 at the university, thus supporting their development into autonomous persons.

Vygotsky (1978) termed that students will solve problem on a higher knowledge level in, collaboration with peers or adult supervision because of the zone of proximal development (ZPD). The ZPD is the zone between the participant's current knowledge level and their wanted knowledge level.

"The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state."(Vygotsky, 1978)

In the Svartöberget project the students are given the opportunity to enter the ZPD both in the technical area and the project process domain through collaborating in and between groups.

Information technology as support for learning

To educate students in civil and architectural engineering in a city planning project, tools and methods for parallel processing are needed. Computer skills and information tools are often not prioritized. Säljö (2000) states that information technology makes visualization possible in the area of education where simulation of reality activates more sense than text will do. A common method to teach students better computer skills is to use tutorials in software, enabling the teacher to concentrate more on the theoretical height in the course.

Concurrent Engineering

Concurrent Engineering (CE) is a systematic approach with aim to minimize time and maximize quality through design and development processes. CE is a popularly approach to product development and design in the manufacturing industry. CE is today more used as a philosophy combining many types of tools and theories (Prasad 1996). Product developing has forced to be more effective because of today's market and the whole business world. CE is a result of rapid solutions for product design process and need strategic plans for developing products for a changing market. Winner et al. (1988) stated that two key principals for CE are integration and concurrency. In a course were times to wait for different disciplines with a case, necessary of methods and tools are obvious.

Collaborating and communicating is two of the key factors in CE to facilitate environment between individuals and also in the organisation. Interfaces in product design and early steps for planning are a central topic in the CE theory (Prasad 1996). Variables and constraints for the design depend on interfaces that will solve information sharing and connect activities in developing process.

3. METHOD

Case study Svartöberget is a study of a project course where students, supervisors, teachers and course managers all are in one process. People in processes are best studied in a situational context, thus suitable for a case study, where multiple sources are used. The results of the multiple sources, as direct observations, documents and surveys, was combined and analysed as triangulated data (Yin 2003).

Direct observation was possible since the first author acted as the information manager during the course. Direct access to all documents produced was at hand and also control over the information flow in evaluation of the course. Logs of work progress and protocols from group meetings have been used as data in the case study. The project plan for the educational program, the course and the project had a central meaning. Dynamic documents as guides for the student groups at the web portal have also been data for the case study.

A web based survey was issued after the course to collect an evaluation from both students and supervisors. The survey was divided in two sections; the first part had predefined questions to capture the overall idea of the project course and the second part gave the opportunity to express with the respondents own words their opinions. Coding the evaluation result, from the case, give a basis for analyses (Yin 2003). The empirical outcome from the survey was coded into seventeen criterions in the BEACON model (see figure 2).

Data analyses

The unit of analysis for the Svartöberget project has been the project itself, the persons engaged in the project and the data produced in the project. The time frame of the project was 5 months preparation time, 5 months conduct and 1 month of evaluation. The results in the evaluation from the students were analyzed with the BEACON model (Khalfan 2007).

BECON is a model presenting the readiness assessment of case studies in construction engineering. The evaluation report from students and supervisors present important grade of different criteria in project based education with concurrent engineering. The grade of importance is split up in percent, where the most important criteria set as 100% and the other criteria's is in relative to the most important for figure 2.

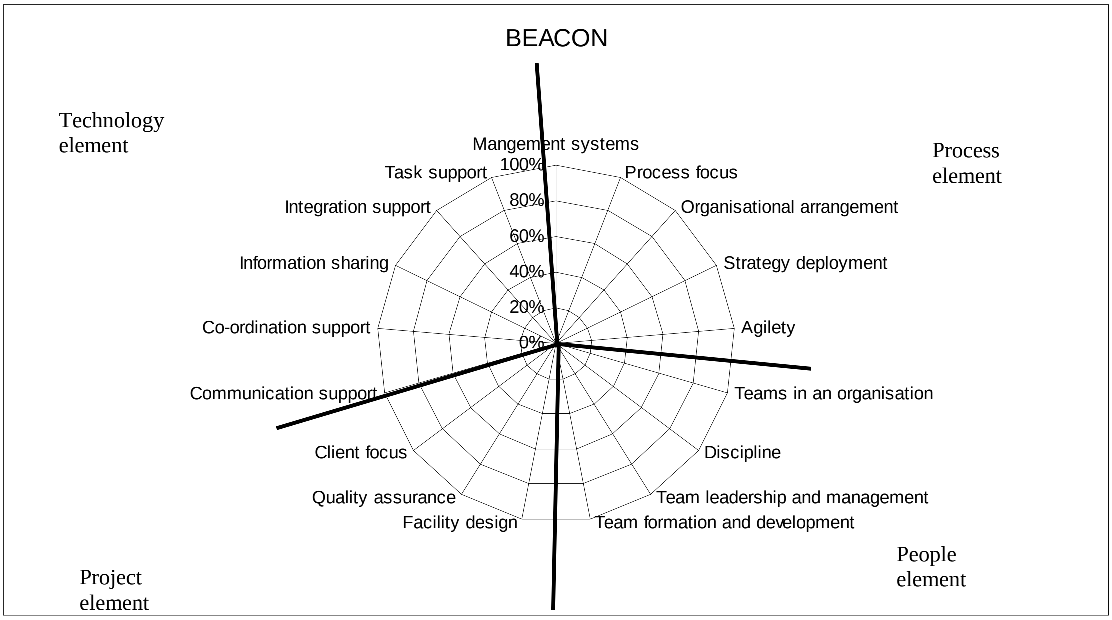

Figure 2: Important grade of CE elements.

Validity and reliability

The reliability in the study has to be seen as acceptable knowing that 40 % of the students went to the web survey and 50 % of supervisors answered our survey. For validity to describe CE as theory for education in construction engineering can we see that our method for collecting and analyzing data shows results that we search to measure.

4. CASE STUDY SVARTÖBERGET

Preparations

The structure and goal for the course was formed by a group with knowledge in each technical specialisation. The supervisor group was formed one year before the course start-up. In total, twelve persons worked with the planning of the course: one course examiner, one project leader, eight supervisors, one ICT coordinator and one coordinator for group processes. Different specialisations met in the Svartöberget project. To give students a technical height in their specialisation, the course was split up in six parallel tracks: Place Design, Urban Planning, Environmental Technology, Structural Engineering, Geotechnics and Mining and Building Management. The six specialisations were organized in 21 sub-groups with different tasks. The sub-group tasks were planned in relation to their specialisation, but in parallel connected to the Svartöberget project.

The supervisors organized the project so that students will manage the project and also work in parallel. In reality, urban planning is made some month before detailed planning of structures (Nordstrand 2000). For the management group this was a problem that had to be solved, so CE theory was applied. The idea was to start the Urban Planning task one week ahead and hold Structural Engineering two weeks after the rest of the groups had finished.

CAD tools and Internet portals were used as the main ICT tools. The management group had a vision of merging the 3D-models from the different sub tasks into one virtual reality (VR) model for the entire area. The purpose was to support overhead planning, quality control and a project work design. To train the students in building up environments for urban planning projects, a VR model of downtown Luleå (the Luleå model) was created as a template for the Svartöberget project. Technology to meet in the same digital environment was tested in this model. The Luleå model is based on geographical data from 3D coordinates, orthographic photos and basic map data. Buildings in the VR model were created from 2D maps where corners of existing buildings were pointed out. Photos of facades and roofs were combined with the 3D model to form the Luleå model. An ICT coordination student group was organized in the course to handle information flow and CAD models in the project. One student from each of the six specialisations joined the ICT coordination group and worked halftime with information related tasks.

Examination

Examination for project courses needs multiple judgment criteria. Technical specifics, common knowledge, project related work and group process reflection became the ground criteria for examination. An object view from the supervisors, with focus on project based education with CE instead of technical results was the plan. The students were examined in five different ways:

- Project work in project
- Presentation, vocabulary and writing
- Group process
- Theory exam
- Practical exam

Conduct

The 84 students at Civil and Architectural Engineering formed 21 subgroups right after the course start (see figure 3). Each sub-group started with a working process to present a group leader to the management group. Contracts handling work responsibility and conflict handling were signed at the beginning of the course. A client organization that could put demands on the participants in the project was not defined. One group with three students formed an operating group in the project. They handled project related decisions and clarified project tasks to groups and subgroups, figure 3.

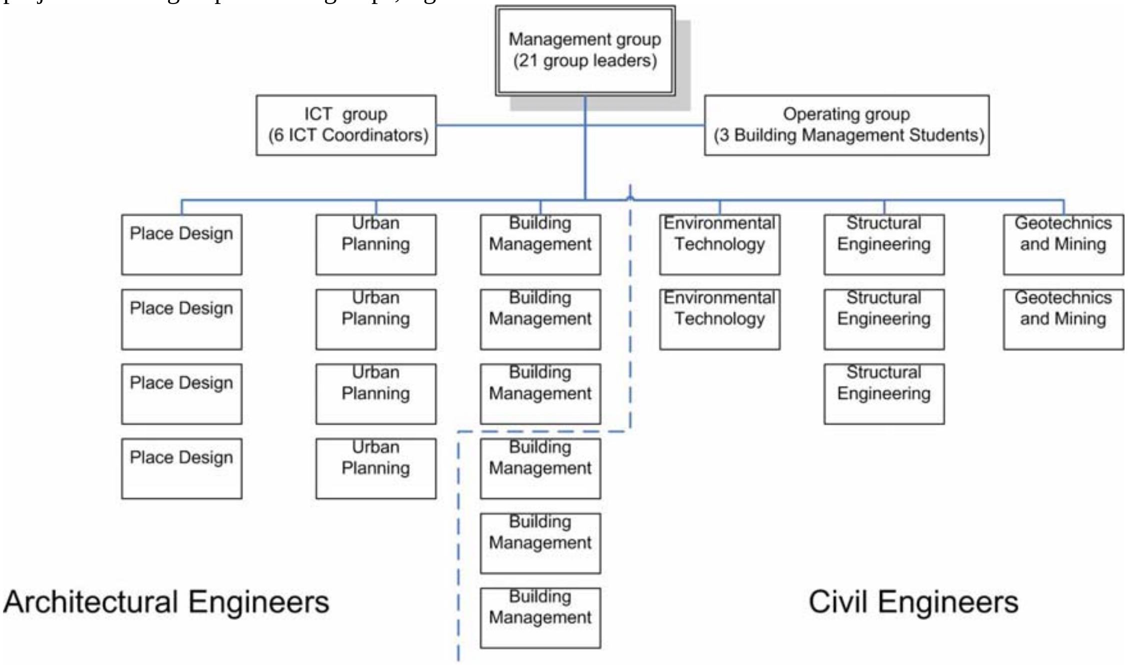

Figure 3: Organisation chart for students groups.

To get an overview and add realism to the project a field study was carried out at the Svartöberget location. All students walked around the area to get their own picture of how the future environment should come across. Another purpose with the field study was to give the students the feeling of how the industrial environment influenced the area.

A planning method for the project work itself was needed, preferably a method that embraced both quality control and a meeting structure. Each group leader had to make an overhead project plan together with their group. Look Ahead Planning, which is part of the Last Planner method, was chosen (Ballard 2000). Meetings were held every week with follow-ups using the Look Ahead Planning schedule. Five week plans were made and every week the past week was checked to follow-up planned activities in the project. The five weeks planning matched the overhead planning and both were revised continuously.

Scheduling and planning lectures in the course was subordinated the project tasks. Three different types of lectures were used in the course: lectures for all students, specialisation lectures and ICT tool laborations. Common lectures were planned in the beginning as a base to stand on for the students. As basic knowledge in sustainable city planning two lectures were offered. One lecture for ordinary knowledge as social, economical and ecological aspects for city planning and one with practical examples from harbour environment and sustainable planning. Project processes in building construction were split up in four lectures: BIM in design, project processes, market and actors and the role of the engineer. The last six lectures with common theory were given by each specialisation. Finally, specialisation lectures were given, varying between eight and twelve lectures depending on the technical specialisation. Lectures in information technology and information sharing were given trough the entire course. Labs with ICT tools were given as open lectures with no specific examination unless the final presentation.

Working in a project, where all students have small or no experience of working with building and city planning, put pressure on the students to seek knowledge in their own technical area. In the beginning, the management group started to slowly create rules to share and present information in the web portal. The four groups in Urban Planning had to specify the area by separating blocks from roads and define the infrastructure type. In parallel to urban planning, the other groups started to sketch on places, structures and technical solutions for the project, without knowledge of a defined area (see figure 4.).

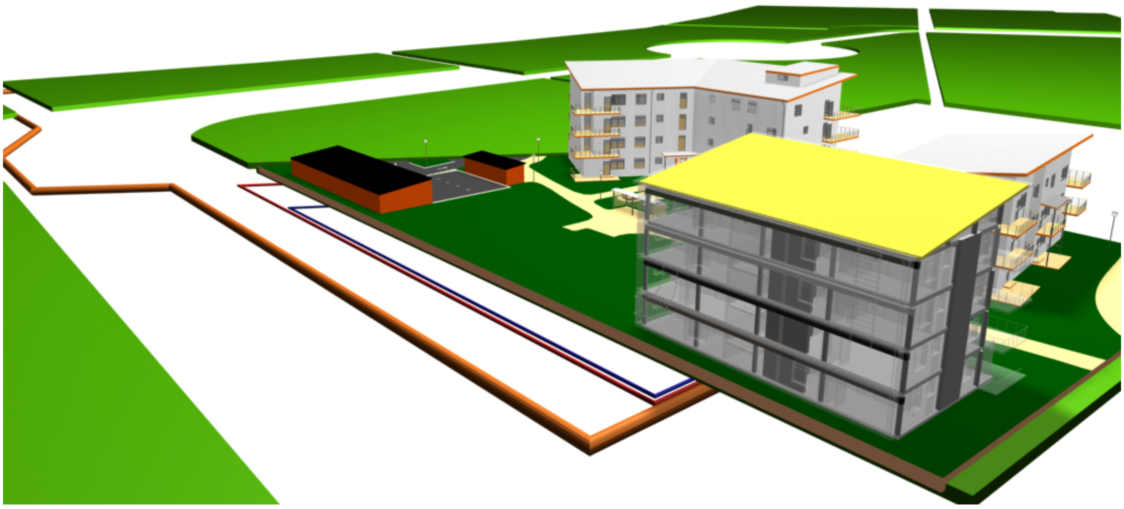

Figure 4: CAD platform for models and visualization

After urban planning was finished, every group fitted their own concept into the plan through iterations. Seventeen students from the Place Design group got one block each and designed the inner and outer environment. Defined boundary conditions for a block was house height, type of building (private, commercial), traffic planning, etc. In the project management group, CE was tested strongest after the urban planning phase. CAD models, drawings and information had to be distributed to sub-groups so all participants could perform their task. Project management meetings were vivid and project tasks were formed by the students themselves to solve a specific problem in the project. New vertical groups developed in the project and new constellations started to work with own tasks that would lead to the final goal. Parallel to the new stage of the project the ICT group carried on their work with ICT strategies.

Project presentation

The last four weeks was dedicated to working on the presentation of the project. Drawings based on 3D models, posters with pictures from inner and outer environment and presentation of calculations for every building were developed. Every group presented their own project report and as an outcome to the society a CD was made.

All twenty-one groups had to present their work orally. The students planned their own presentation, which ended up in a showroom open to the public where municipality, industry, university and private persons joined together.

Evaluation

The results of the course evaluation showed that important elements in the project course were separated between students and supervisors, figures 5 and 6.

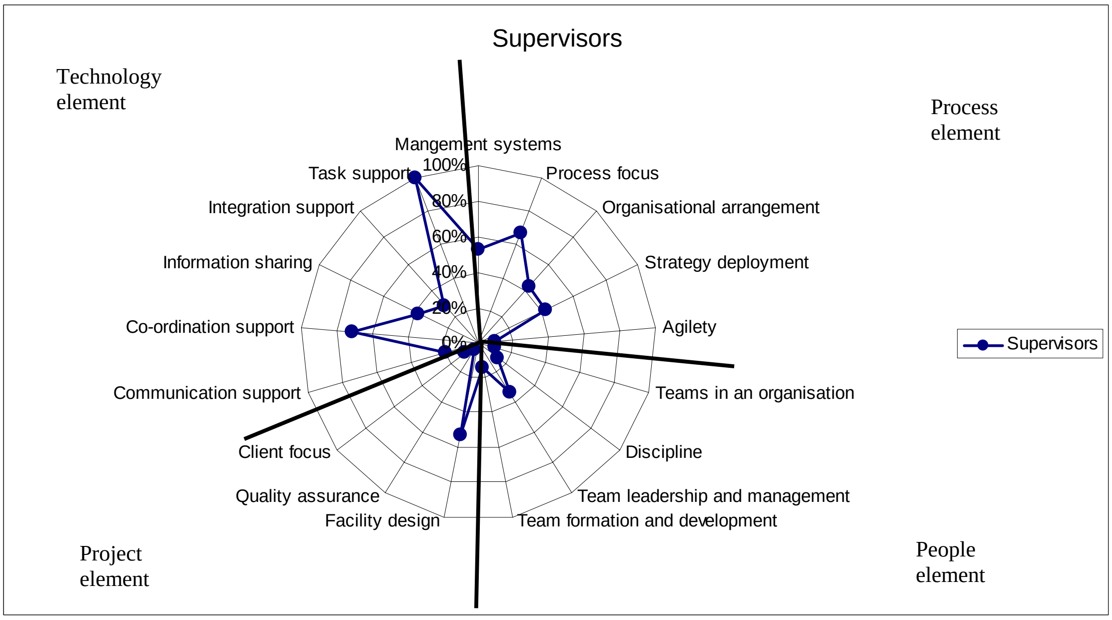

Figure 5: Supervisors important grade of CE elements

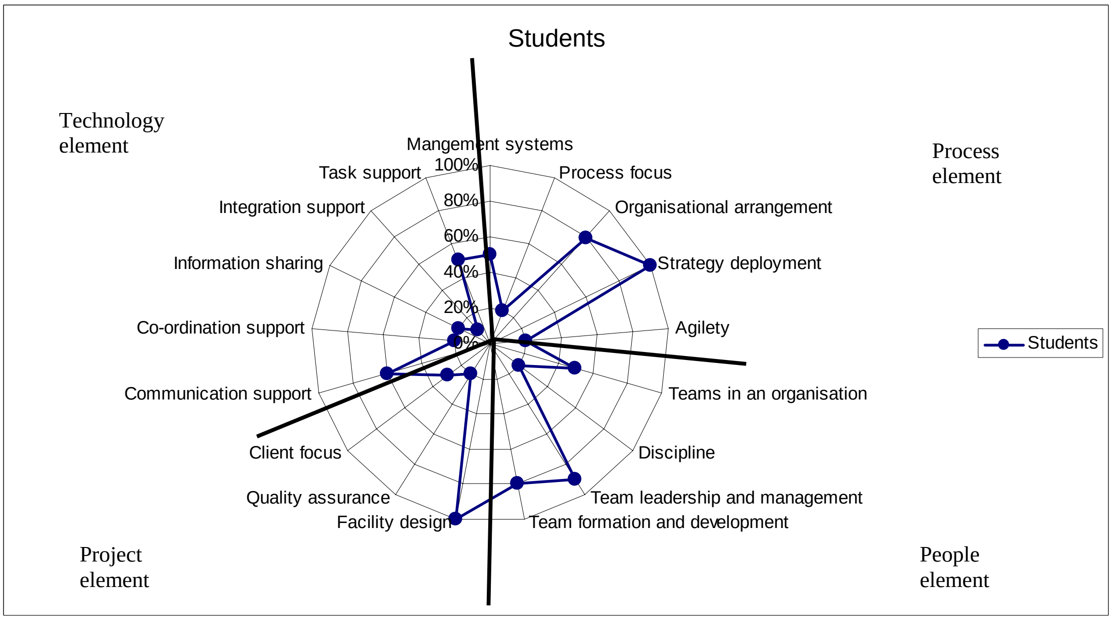

Figure 6: Students important grade of CE elements.

The common favourable opinion of the students is that of the course fills up a gap among a real project in the education. Important negative opinions are the structure and organization with leadership and teams. Undefined buying organization that could put demands on the participants in the project was not clearly defined.

5. ANALYSES

The results in substantial aspect were great, with a good outcome from presentation in reports, physical and virtual models. Bruffe (1993) states that students in collaboration will reach longer when problem solving towards a common goal is at hand. During the Svartöberget project, there was an opportunity to give students knowledge in their technical area that they never would have obtained if it was delivered in traditional class room education. With colleagues and supervisors in the project, the zone of proximal development (Vygotsky 1978) was stimulated in several ways. However, the result of the student evaluation shows that support and organization should have been more structured for a chance of even more knowledge development. The most difficult task in course planning was to define the border between the framework of the course and the creativity in problem solving for the students, which led to a strong student request for better structure. Knowledge in the technical area vs. knowledge in the pedagogical area has to meet in a common strategy in this type of course. A strong observation from the course conduct was that this type of collaborative course poses high demands on the supervising teachers. They too have to collaborate and communicate according to a CE process. Unfortunately, this was unsuccessful and teachers had problems stepping out of their own role as a “teacher by the bench” and start acting as a project member.

CE as an approach can be a god method to organize tasks in a project (Prasad 1996). A method model has to be developed for the course with demands on different actors (both students and teachers). Even if students had to wait sometimes in the project, all groups were working in parallel with their own project tasks. Waiting for information in a project is often traced to a customer decision (Koskela 2007). The ICT coordination student group worked in parallel to the project with standards and templates for the ICT tools that was used in the project. A more integrated role for the ICT coordination group, in the operative group would have given an opportunity to coordinate information and avoid problems with information sharing (Amor & Clift 1997). The VR-model, that was the central unit as a quality tool for the project, should support collaboration in the placement of buildings and infrastructure. Functionality in the software partly prevented quality control through the project because of limited interfaces to some used CAD systems.

Analyzing the four elements in CE can result in the answer that *personal element* can seen as important element for the students but not for supervisors in the course. A resource for group processes was defined in to handle personal conflicts and team leadership. For supervisors was that area solved and focus landed some ware else. In students view wasn’t the project organization ready to control *personal elements*.
The *task support* was much more important for supervisors that it was students who focus their evaluation on *facility design*. A conclusion of this can be that students were more result oriented; wile supervisors looked more at the learning process in the course.

6. CONCLUSIONS

Concurrent Engineering can be useful as a collaborative method for educational projects in engineering education. Three important areas that appear in the analyses of the case study to succeed with concurrent engineering in project related education is:

- Setting up a clear goal and define project boundaries for students and teachers
- Define good structures for information handling, especially for supervisors
- Introduce a client role that continuously could define requirements for the product

CE as an approach to construction project related education can be used, if the defined project contains smaller sub-tasks for the students.

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