Organization and Assessment of a Multidisciplinary Project

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Abstract

The Bachelor Architecture, Building and Planning in Eindhoven is quite broad since it prepares students for six Master specializations: Architecture, Urban Design & Planning, Structural Design, Building Physics & Services, Real Estate Management & Development, and Construction Management & Engineering.

The Bachelor offers an exceptional multidisciplinary project, aimed to train students with knowledge and experiences in integral design. Developing this project has been a long route that took place over many years. This paper presents issues, as programme and time scheme, required products, assessment method, learning goals, as well as underlying principles. Major changes in the last 10 projects (2007–2013) can be explored because students were frequently asked to fill in enquiries.

Over the years, the multidisciplinary project is developed to be successful in preparing students towards the complexity of today's practice. Here, the real strength of a broad Department stands out well, enabling students to work in multidisciplinary design teams on complex actual themes.

Keywords: design team; multidisciplinary; organization, coaching, assessment system.

1. Introduction

"Eindhoven" presents itself as a Department where integral design is *the* key issue. Today's society becomes more and more complex that reflects immediately in today's building demands. In building practice there's a great demand of broad educated engineers, who have thorough knowledge of a specific discipline, but who are also able to cooperate in a team. And who are able to overview the total process. This trend is seen in most engineering domains: engineers of the future will likely work collaboratively in multidisciplinary teams of technical experts (Clough, 2004).

This is why the Bachelor Architecture, Building & Planning (ABP) at Eindhoven University of Technology (TU/e) focuses on multidisciplinary design incorporating three major directions: Design, Technology and Management. The central theme of the department is to educate engineers, who are schooled to become a specialist in a specific field in the Master, while the Bachelor gives them the ability to work in a team as skilful conversation partner to all other disciplines. For this reason the Bachelor (of 3 years with 180 ects = European Credit Transfer System) is broadly-based (Figure 1). Each year has two semesters and a semester has two quartiles (15 ects), each lasting 10 weeks. All quartiles have 3 parallel blocks of 5 ects, always incorporating two lecture based blocks and one studio-based block.

Students impart basic knowledge in all building areas by the 56% compulsory courses, almost equally divided over Design, Technology, and Management. The program also offers students ample opportunities with about 28% optional courses (to be approved by the Exam Committee). With optional courses a student is able to further widen knowledge however a student can also deepen knowledge oriented to a specific discipline.

A major educational goal in the Bachelor is to train students in designing: architects as well as all kind of engineers. Therefore, 1/3rd of the Bachelor program is organized for studios (Figure 1). Here students work on practice-based design projects using Design-Based Learning (DBL). Students learn to integrate and apply knowledge in DBL (Wijnen, 2000). DBL elaborates on educational principles of problem-based learning (PBL) (Graaff, & Kolmos, 2003). PBL makes use of knowledge accumulated and acquired in courses and lectures, and applies this in professional projects in a studio setting to reach to a solution of a specific problem. PBL is based on the idea that students develop skills and integrate knowledge by solving ill-defined problems (Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar, & Ryan, 2003). DBL is often used in engineering education, although there are considerable differences between domains (Gómez Puente, Eijck, & Jochems, 2013), particularly in characteristics of projects, role of teacher, and design elements. In architectural design, education studios have been widely adopted (Swagten, Moonen, & Wennekes, 2010; Goldschmidt, Hochman, & Dafni, 2010). Here, desk critics is given by a tutor and is the major pedagogical method: Criticism is the act of making judgments and evaluations from tutors to students (Graham, 2003) to communicate design knowledge, and to bridge the gap from theory to practice (Salama, 1995).

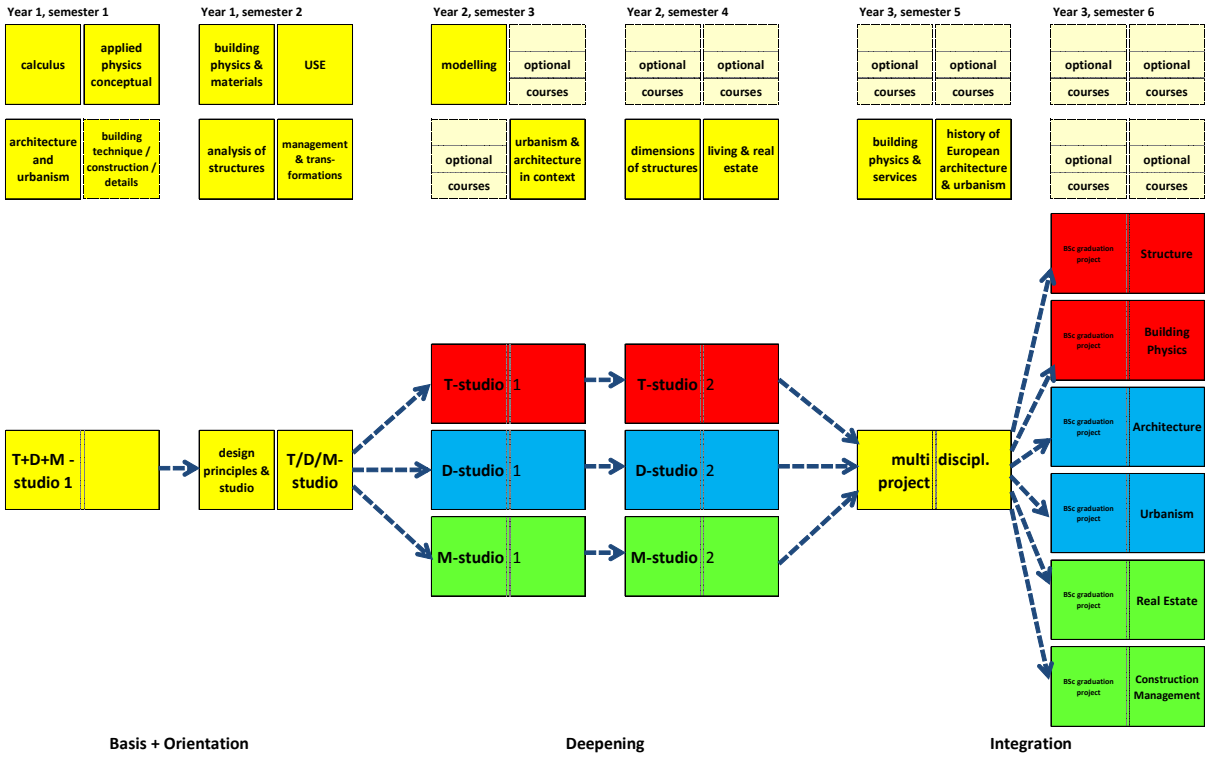

Figure 1: Outline of the Bachelor Architecture, Building & Planning at TU/e. A block represents 5 ects (studios combine 2 blocks). The deep yellow blocks are compulsory for all to get acquainted with basic principles

Figure 1 shows the curriculum of the Bachelor. The bottom row indicates the flow chart of design studios with possible routes that a student can opt for. First, the 1st year studio focuses on orientation, learning how to design, and on facilitating freshmen to make a decision regarding their preferential direction. Next, in the 2nd year a student has to choose out of three directions: technical (T), design (D), or managerial (M). Here students become more disciplinary oriented. After that, in the 3th year the three directions assemble in the *multidisciplinary* project (called "multi"). Here design teams of 6-8 students receive an assignment for an actual theme, focusing on all levels from urban planning up to detail and construction. The idea is that students learn how to cooperate in a design team, starting from the contribution of one's discipline. After Multi, in the last semester of the 3th year, a student is free to choose one of six graduation studios: Structure, Building Physics, Architecture, Urbanism, Real Estate and Construction Management. The six directions correspond to the six directions that the Master offers.

Students have to create individual designs in all studios within the context of the defined problem. So students are individually marked in all studios. This also counts for the multidisciplinary project. Awarding individual marks to students working in a design team requires a specific organisation. The method used to reach individual marks in the multidisciplinary project is described in the following paragraphs.

2. Programme of the multidisciplinary project

In early years the multidisciplinary project was organized more or less comparable to other studios. But since the pith of different disciplines involved, lays in different phases in designing, it is difficult to organise a design process where students cooperate from the very beginning. In a traditional setup usually urban and architectural designers take the lead at the start of a design process and it is difficult to involve technical and real estate specialists to take part in the early design phase. Technical and real estate specialists are used to focus on activities that require a kind of lay-out. However if they take no part in the early stage of designing this does not lead to a desired situation in a multidisciplinary project since crucial options arise when first decisions are made. But also for urban and architectural designers the traditional setup wasn't ideal, because technical and real estate specialists put pressure on their design process, often at the expense of proper urban analyses or context studies.

Started in 2009, the undesired situation is tackled by introducing workshop weeks at the start (Figure 2) were urban and architectural designers perform proper analyses while all other disciplines are incited to consider technical or

functional concepts (for instance a concept like a zero energy building *needs* preceding research and will have significant impact on the design). These workshops also help in a way that all students deliver pieces of work direct at start that can be assessed. So tutors receive more students' products that enable them to assess the whole semester.

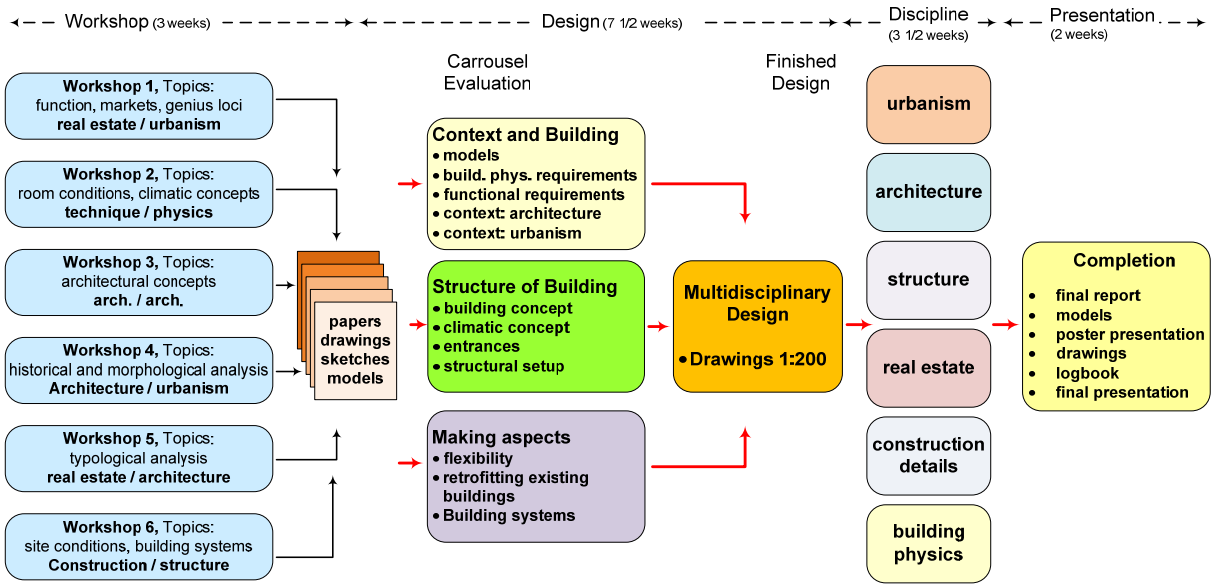

Figure 2: Flowchart of the multidisciplinary project. The project has four phases: the workshop weeks (6 workshops by combined disciplines); the design weeks; the discipline weeks (with 6 disciplines) and the presentations week. Note that the size of a block does not refer to the time schedule; the duration of each phase is represented in Figure 3

The topics in all workshops are based on a combination of two disciplines with prescribed items to be analysed. Each design team sends two representatives to a workshop (so every student joins two workshops, one supervised in a morning session and one in an afternoon session). With 20 design teams of 6 students, there are about 40 students in every workshop. In a workshop a group of 2-4 students elaborate on a specific topic in relation to the actual theme. The goal is to present the condensed findings to all other students in the workshop. In this way all students of a discipline acquire massive background information that can be useful in the later design weeks.

There is for instance a workshop where students perform all kind of urban analyses (historical, morphological functional, et cetera) or a workshop where students discover all kinds of climatic concepts. While students in another workshop give each other detailed explanations about which building systems are applicable in the given context and how the specific site conditions can be handled in a design.

Apart from gathering disciplinary output, supervisors may also take time in the workshop weeks to instruct (technical or real estate) students how to anticipate in the early design weeks in their design team. With all members in a design team cooperating from the outset a better overall result is within reach if more facets of the actual question are considered from the very start.

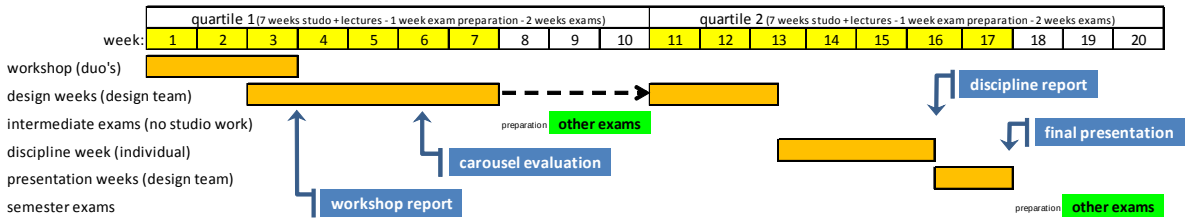

Figure 3: Outline of programme of the multidisciplinary project (2 quartiles of 10 weeks) in weeks including the four assessment items: the results of the workshops, the carrousel evaluation, the discipline reports and the final results

3. Learning goals

The multidisciplinary project embraces eight learning goals, divided into three sections: process, product and presentation.

The section "*Process"* handles the integral design of buildings. Making a compound design requires teamwork and is complex by nature: it requires many expertises and there are several design goals. It is impossible to cope with these goals without teamwork, so a student shall learn how:

1 to cooperate and to value other domains in building;
2 to develop a joint vision for an actual theme and be able to develop this into concrete design goals;
3 to organize an integral design process in such a way that disciplinary depth can be separated from the total;
4 to realize the mutual developed design goals of a team;

The section "*Product"* handles with the (technical) details of a building in respect to the individual professionalism and the individual design goals. The quintessence is how to apply the individual know-how and how to make this concrete into one or more design goals, so a student shall learn how:

5 to generate and evaluate alternative concepts;
6 to prove that the preferred concept meets the design goals (by calculation, simulation, drawing et cetera);

The section *"Presentation"* handles with presenting and defending the design, so a student shall learn how:

7 to clearly present the design confined to the main issues to a group (in a carrousel and in the final presentation);
8 to present the design in drawings, text, posters and models.

These learning goals are a consequence of two basic assumptions: testing the cooperation (by considering the way a design team reaches a result) and an individual testing of a student (by considering disciplinary results). The team result is checked on qualitative aspects in regard to design requirements and on how partial aspects are integrated.

4. Way of supervising and coaching

One of the complexities in organizing a multidisciplinary studio is the many tutors that are involved. In this case six disciplines are considered: architecture, urbanism, building physics, structure, construction and real estate. Because of the large number of students interested in architecture this discipline has two supervisors, bringing the total number of tutors to 7. It is also very important to assist and supervise the process that takes place in the design teams since bachelor students have little experience with this complexity. In this course there are two coaches (called "monitors"). This brings the total number of tutors involved to 9. One of the tutors coordinates the work of students as well as the cooperation between tutors.

An overview of the total time needed for coaching is represented in Table 1. Reference is the last project in 2013 where 128 students participated in this studio (the two process coaches have only tutor hours, since they also are involved otherwise in the studio).

Table 1: number of students, tutors and time required in the project of 2013

Discipline / coaching	No. of students in 2013	Tutor hours	Coordination meetings, start meeting, evaluations, reports assessments, final presentation, feedback, et cetera
Urbanism	12	53	81
Architecture	23	101	81
Architecture	20	88	81
Building physics	13	57	81
Structural design	16	70	81
Construction + detail	8	35	81
Real estate	36	158	81
Process coach (monitor1)	68	39	-
Process coach (monitor2)	69	39	-
Coordination	-	-	120
total	128	641	687 in total 1328 hours ~ 10,4 hour/student

The time required to provide adequate tutoring can be compared to Table 2 showing the effort for organizing traditional studios in the 2nd year. Here studios in groups of 8 students (with 2 quartiles of 7 weekly meetings by a tutor that takes about 4 hours) are considered. Additional 1 hour is needed to mark an individual report and about ½ an hour to provide individual feedback. Based on this reference studio the multidisciplinary studio requires a fair comparable amount of tutor hours: 10,4 hours per student compared to 10,0 hours per student (although the focus is largely shifted from individual tutoring towards collaborative tutoring and coordination).

Table 2: time required for an equivalent project setup of 128 students

Discipline / coaching	16 groups of 8 students	Tutor hours	Coordination meetings, preparation, et cetera	
Tutor 1	16	136	12	
Tutor 2	16	136	12	
Tutor 3	16	136	12	
Tutor 4	16	136	12	
Tutor 5	16	136	12	
Tutor 6	16	136	12	
Tutor 7	16	136	12	
Tutor 8	16	136	12	
coordination	-	-	100	
total	128	1088	196	in total 1284 hours ~ 10,0 hour/student

By comparing Table 1 to Table 2 it is clear that the multidisciplinary project needs much more coordination compared to a traditional studio (about a factor 3,5). This is needed because the team of tutors has to cooperate in itself. However since students in a design team work close together, tutor hours of supervising students can be reduced (by a factor 1,7). And by comparing the total hours needed to organize the multidisciplinary project to a traditional project, it is found that there are just 3,5% extra tutor hours needed.

5. Individual evaluation of multidisciplinary efforts

Although the multidisciplinary project is a team activity students are individually marked instead of getting an average score for the whole team. However individual evaluation of this project is quite complex because there are several supervisors from different disciplines involved as well as there are several assessment components (of individual students as well as of design teams). But by asking several pieces of work that can be assessed and by providing students with a clear overview of the way this results in the final assessment, it is well feasible to come to individual marks. The different assessment components that are asked, are:

- Carrousel evaluation (design team) where all teams present their concept in parallel sessions (Proveniers, & Westra, 2009). Each design team presents 4-6 times to different groups (of supervisors, coaches and guests). They receive feedback at every presentation from the different groups.
- Discipline report (individual) that consists of two parts: Part A represents the individual findings in the workshops, while part B represents the discipline requirements. This part also reflects the influence of the other disciplines on the individual work as well as vice versa (in maximum 30 A4-pages);
- Final report (design team) that provides an integral and appealing description for an interested public: how is the actual theme interpreted, which opportunities are taken (in respect to the three aspects), in maximum 10 A3-pages;
- Logbook (individual), that consists of:
  - representation of weekly progress showing the most important activities and design decisions as well as the cooperation with the other team members (in text and/or sketches, maximum 1 page/week);
  - short reflection on the teamwork within the team (maximum 1 page);
  - evaluation on the cooperation of the other members in the team (maximum 1 page).
- Models (design team) in triplicate. One model explains the urban embedding (about 1:1000), another model explains the building design (about 1:100) while the third model shows a 1 meter section of the façade with technical details (about 1:20);
- Poster presentation (design team) of 4 posters. The posters and models will be exhibited in an exposition;
- Final presentation (design team) by PowerPoint giving an adequate overview of the results;
- Final booklet (design team), incorporating all posters and an abstract of 150 words.

Table 3: weight of different pieces of work

Aspect	Criteria, the student is able to:	assessed by:	based on:	weight
Individual product	Individual generate alternative concepts, select a preferred concept and prove that this concept meets the design goals (by calculation, simulation, drawings et cetera)	Discipline supervisor	Discipline report	50 %
Team Product	Select, underpin and validate the alternatives of the carrousel evaluation and in the workshops for urban embedding, design of buildings and feasibility (integrated as a whole).	Team of coaches and supervisors	Carrousel evaluation	0 %
	Develop a vision as a team for the actual theme and make this concrete to a program of requirements and to design goals. Realize, integrate and present as a team the requirements of different parts (urban embedding, design of buildings and feasibility). Make a presentation as a team for a large group.		Models, posters, and final presentation	50 %
Final mark of student (maximum)				10
Process	A balanced contribution to the team and final product. The coach assesses the contribution en corrects the final mark of an individual student: if positive max. 1 point extra, if negative max. 2 points reduction to the final mark of a student.	process coach	Experiences during coaching, Logbook	+1 -2

A student fails if the final mark (after correction by the coach) is less than 5,5 (in 10) *and* also if the discipline report is marked less than 5,5 (in 10). In this way team work is important for a student, as well as discipline outcome. As for example, a mediocre student cooperates in a team with outstanding students, it is well possible that the team result is marked excellent, yet that the student still fails due to an insufficient discipline mark.

Figure 4 shows an example how this works out for a team, combining results of seven tutors. The team product is marked on 3 parts: urban embedding, design of buildings, and feasibility. For each part marks are given by two tutors. The presentation of the team is marked by all tutors. The overall mark for team work is the average of the mark for urban embedding, design of buildings, feasibility, and presentation. This overall mark counts for half of the result of an individual team member. The other half comes from the individual mark awarded to the discipline report. When these two partial marks are combined the correction of the process coach (+1 or -2) is processed if applicable.

The correction of the process coach is hardly ever applied. Yet, it is important to have this possibility because every so often there is a student who impede the design team by refusing to cooperate and instead to just concentrate on one's discipline requirements. Without a correction, this student could easily pass in this system.

Team A	tutor urbanism	tutor architecture + context	tutor building physics	tutor real estate	tutor construction	tutor structure	tutor architecture + detail	average
Quality of the team product								
Urban embedding	**7,50**			**8,00**				**7,75**
design of buildings		**6,50**	**7,50**				**7,00**	**7,00**
feasibility					**5,50**	**6,00**		**5,75**
presenting the team product								
• posters	7,00	8,50	8,00	7,50	7,00	8,00	7,00	**7,57**
• drawings	8,50	7,00	7,00	8,00	8,50	7,00	7,50	**7,64**
• Modelles	7,50	8,00	8,50	7,50	7,50	7,00	8,00	**7,71**
Mark for presentation	8,50	7,00	8,00	7,00	8,00	8,50	7,00	**7,71**
							overal mark team work	7,05

Figure 4: example of the way the result of a team is assessed. All 7 tutors provide 5 marks on different items. This overall mark for team work counts for half of the result of an individual team member

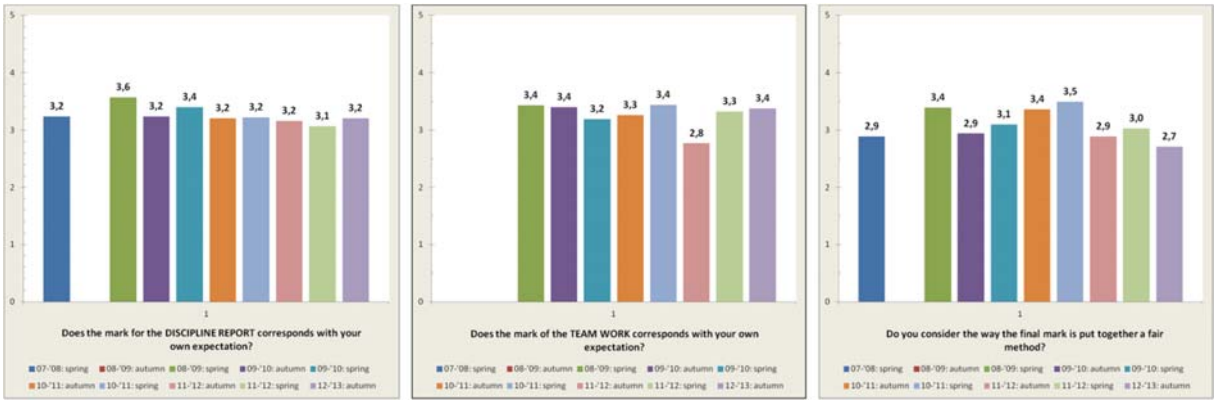

Figure 5: results from students' enquiry of 9 assessments (from 2007-2013) on a 5 point scale. The graphs left shows how the assessment corresponds to expectations regarding the discipline report, the graph in the middle shows how the assessment corresponds to expectations regarding team work. The graph right shows in what way students consider this method a fair method

In Figure 5 three graphs are shown derived from a sequence of students' inquiries (at the end of every semester). These graphs show that the given marks correspond quite well with students' expectations in regard to the two main elements (discipline report and team results). However, Figure 5 also shows a rather less score for the total method. In some feedback meetings students explain this by pointing to the exclusive requirement of the discipline report, while others point to vague criteria of correction by the process coach.

6. Conclusion

Generating individual marks for students working in design teams is complex by nature. However it is important for engineers in the building industry that they learn how to cooperate in a team where each student is responsible for a specific discipline. The multidisciplinary project in the 3th year of the Bachelor Architecture, Building and Planning is intended to learn to work together on an actual theme and at the same time to bear responsibility for a specific field.

The multidisciplinary studio is anything but a weak reflection of the building practice but an educational form where students are confronted with complexity that requires the cooperation of a design team. In the Multi studio students don't act like architects, building engineers or other counsellors, but every team member is challenged to make an individual contribution to the integral design starting from one's own knowledge and interests. The complexity of today's social and societal issues needs this integral approach, with topics like "energy neutral" or "energy-producing" (block of) buildings. This example of a topic is one of the main items in Multi, however always regarded in connection with other building requirements. This topic is more and more pressing, because according to European regulations the energy-neutral topic has to be settled within the next decade. This topic requires much more than new services concepts and solutions, and it will at the end have also a huge impact on the urban level as well as architectural level.

This complexity requires a specific studio setup. This paper presents a way how this complex programme, the organization of tutors, individual assessments (being part of team work) and the kind of pieces of work takes place in the multi project at TU/e. The presented way of organization shows that this can be done in a fair comparable amount of tutor hours (compared to other studios) although there are much more tutors involved in the multidisciplinary studio. In comparison to common studios a shift is noticed in tutor hours from individual coaching towards a much larger amount of mutual activities and meetings, mainly meant to encourage tutors to gear to one another.

The paper also shows a setup with workshops by which all disciplines have to explore specific themes corresponding to a discipline. By starting with workshops preceding the design process all students have to develop concepts belonging to their own discipline. In this way students of technical and real estate oriented disciplines are encouraged to participate in the early stages of the design.

The paper gives an overview of all pieces of work that students have to deliver (some are individually made, others are team results). Based on these results the assessment system that is used is described. This assessment system has two major items: a disciplinary report (that is individually made) and the design results (made by the design team). The average of these two marks may be corrected by the process coach ("monitor") by +1 or -2 points. The result needs to be at least 5,5, however there is also an additional requirement that the mark for the disciplinary report needs to be at least 5,5.

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