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ScienceDirect

Procedia - Social and Behavioral Sciences 119 (2014) 549 – 556

Procedia Social and Behavioral Sciences

27th IPMA World Congress

Interdisciplinary Design: Influence of Team Structure on Project Success

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Abstract

The conceptual building design phase is crucial in the overall design process, determining the life-cycle quality of a building. Early collaboration of architects and engineers should provide for creation of new knowledge and solutions beyond specific scope of disciplines. This paper presents the research on collaboration of students of architecture and structural engineering in conceptual design phase, within interdisciplinary design class, at the same time the student competition Concrete Student Trophy at the Vienna University of Technology.
The research focus is to find out the impact of the team composition on the design quality in terms of competition success. The first findings generated through the logistic regression indicate that more architects are beneficial to the probability of success, while more civil engineers in the team are harmful to the probability of success of a student group in the Concrete Student Trophy. The future research will explore the impact of further drivers such as professional experience or former acquaintance of team members on the success.

Keywords: Conceptual Design, Interdisciplinary Design, Design Study; Collaborative Planning; Sustainability; Energy Efficiency

1. Introduction

The earliest design stages are dominantly responsible for the latter building performance during the lifecycle - conceptual design plays crucial role for building design quality. Therefore, the interdisciplinary collaboration

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doi:10.1016/j.sbspro.2014.03.061

should be initiated at this early stage, when interconnectedness of a project's goals can be recognised, new solutions can be developed through complementary knowledge of different experts, improvements are made easily, and new common knowledge can be created (Wang et al 2009, Rossi et al, 2009). In the early planning phases there is an unlimited universe of possible solutions, however still very few tools, methods or knowledge on actual collaborative, interdisciplinary design, which would be helpful for the process. With project progression, the number of possibilities is decreasing, however the number of available design or planning tools and methods is increasing (Fig.1), creating a large gap between the opportunities and possibilities.

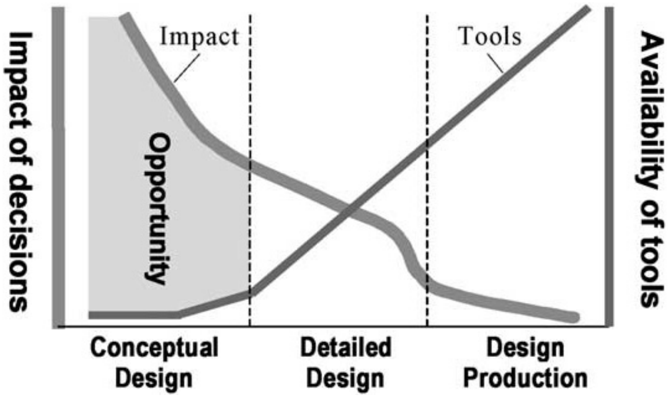

Fig. 1. Opportunities versus Possibilities, Wang et al 2009

Due to the formal university education, which is based on splitting of engineering and architectural schools and disciplines, the students are trained to think in their own scope of activity, instead of working in collaborative manner.

The Department for Industrial Building and interdisciplinary Planning at Faculty of Civil Engineering at Vienna University of Technology together with Austrian Association for Cement and Concrete has initiated in 2006 the Concrete Student Trophy – an international student competition with aim to promote the collaboration of architects and engineers in achievement of innovative formal and structural solutions in material concrete. The precondition for the partaking at the competition is, that competition-team has to consist of at least one architect and one structural engineer. In cooperation with the Institute for Concrete Structures, and, Department for Design and Construction, Faculty of Architecture an interdisciplinary design class accompanying the competition, where the teams consist of architecture and civil engineering students working simultaneously in the conceptual phase.

The Concrete Student Trophy has been carried out for eight years, with covering various tasks: coffee-bar, pedestrian bridge, watchtower, floating bridge, highway station, multi-functional sports hall, flap bridge. The winning contribution of pedestrian bridge has actually been constructed, and is located in the 14th Viennese district.

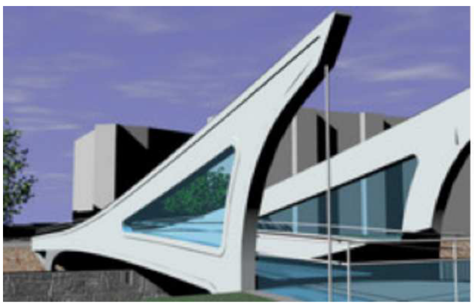

Fig. 2. Link 27 – The winning design and actual realization of Concrete Student Trophy in 2007, Rudolf Brandstötter and Gonzalo Espinoza Ortega

2. Research Question

The main question to be stated in the context of interdisciplinary conceptual design is, why it is so difficult to accomplish the collaboration of the architects and engineers, despite the fact that schools of architecture and civil engineering originate from one faculty: e.g. Bauschule at the Vienna University of Technology, former Polytechnic Institute. The problems in collaboration of architects and engineers in the early phases result from the way they have been educated and thought to think – the architects as generalists with overall view, the engineers as specialists with interest for detailed solution. This attitude which is also reflected in the planning culture, preventing the atmosphere of openness and brainstorming on the problems that lie beyond one's immediate field of expertise.

Interestingly enough, there has been much more academic discussion on interdisciplinary collaboration in conceptual phase in industry and product development (Wong 2002, Sohlenius 1992) than in ACE research. The discussion in ACE research is mostly management and not design oriented, promoting collaboration in order to reduce time and cost; which again can be achieved through integration and concurrent sequencing of activities, supported by extensive use of modeling and simulation tools for planning and but also for communication and data management (Love and Gunarsekaran, 2007). Another approach towards design knowledge is the prescriptive, by the means of technological rule, where design activities and design steps are prescribed through systemized procedures and programs (van Aken 2003 , Sarker et al, 2012).

If a building project is described by the composition of function, form, construction, economy (costs and benefits) and time; the clear focus of the architects is on the form and function, in current education the issue of construction is handled as secondary topic; whereas civil engineers are primarily trained focusing on optimization (seldom conceptualization) of construction, costs and time. In order to be able to jointly collaborate in the early design phases, both disciplines must have a holistic insight but more over interest and openness to discuss the topics beyond their primary scope.

Penna and Parshall (2005) write that "Architects are thought to take holistic view of the problem, and even to go beyond the sphere of different influences to explore other possibilities. However, going too far afield increases the prospects of irrelevant information" (Penna, Parshall, 2005, pp.46). They identify two important phases in a design process – analysis and synthesis. In the analysis phase the problems are identified and classified, in the synthesis the fragmented parts are put together to form a solution. This structured approach to the design process is very suitable for the engineers, trained to focus on finding concrete solutions for singular problems, much more than offering holistic concepts. On the other hand, the architects might find it inhibiting for creativity, as well as in oversimplification and abstracting of the problems.

One of the problems is the approach to the designing - the architects are mostly generating the first ideas intuitively, whereas the engineers trained in scientific manner work in more analytic fashion.

De Jong and van der Voort (2005) discuss on the nature of design, and whether a designer can be also designated as a scientist. They basically distinguish between design study and study by design, where design study is a typical intuitive approach of generating a solution only partially driven by boundary conditions and parameters like building site, spatial program, and others – the imaginative interpretation of designer delivers the "unique" solution. The study by design aims for generation of knowledge, exploring the effects of the input parameters on the output variants. This method is more related to the empirical research often involving experimental research (scenario-based design), or employing various tools (BIM, CAD etc.).

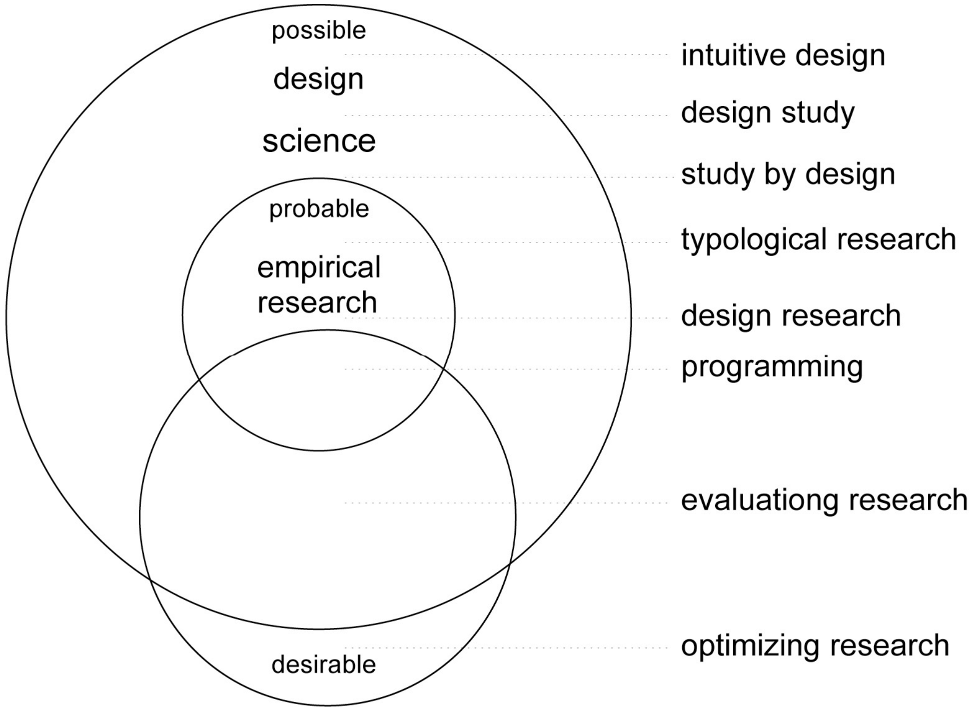

Fig.3 . Design Approaches: from possible to desirable , after De Jong and van der Voort, 2005

In order to provide for successful collaboration in conceptual phase the "bridging" of the gap between the intuitive and rational approach is necessary, for example through combining the prescriptive with descriptive approach (Zeiler and Savanovic 2008), but also through creation of possibilities for setting and creation of joint aims and vision statement, which are helpful in creation of "common" professional language.

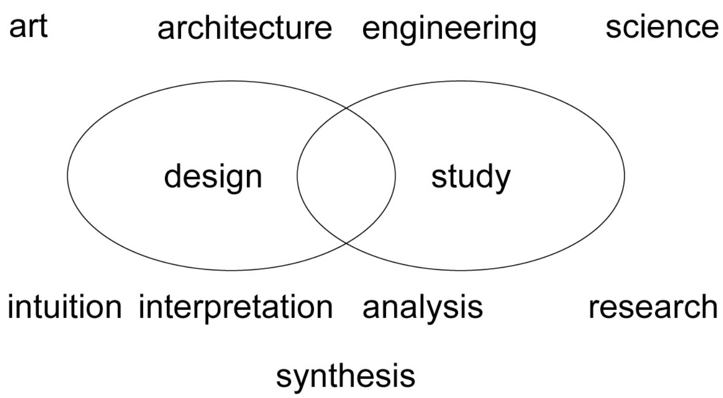

Fig. 4. Spheres of scope of design activity, after De Jong and van der Voort, 2005

3. Literature review

There are numerous attempts in the teaching and research to promote, but also to observe and measure the effects of the interdisciplinary collaboration in the AEC industry. Sturts-Dossick and Neff (2011) observe and examine the collaboration of collocated professional teams of different disciplines using virtual environments on the real project, where key elements of communication and knowledge exchange are identified, and the term of messy talk, as unplanned, unforeseen and unanticipated brainstorming, is established. In further research they examine students collocated on two different universities interacting on online project, using different virtual platforms for communication and management as well as building information modeling software tools exploring alignment of technology, talk and task. Messy talk in this setting is necessary in order for students to learn from each other and synthetize their knowledge (Dossick et al 2012). In the research of building information modeling (BIM) and data exchange between disciplines working on a shared model Plume and Mitchell (2007) carried out a design-class in multi-disciplinary setting, involving students of architecture, mechanical engineering, construction management, landscaping, environmental sustainability. The emphasis of this design-class was on the use of technology and the IFC interfaces used for data transfer between the models, and less on the communication or people related issues.
Zeiler and Savanovic (2008) use the morphological overviews method as combination of methodical design as prescriptive, and reflective practice as descriptive approach to ensure good communication in multi-disciplinary collaboration in teaching and test it in workshops with practitioners, however only 43% of participants find the morphological overviews beneficial for final design. At Vienna University of Technology an experiment comparing the performance of integrated teams with the performance of the teams working in traditional, segmented fashion in multi-disciplinary design class was carried out. The class was organized as a student competition, however no significance could be contributed benefiting either of the working methods in terms of overall design quality Kovacic and Sreckovic (2012).
Especially the BIM oriented research works intensively with multi-disciplinary student settings (Kolarevic 2000, Ramahalla et al, 2011) , however the focus is mostly on the performance of technology and process efficiency, and seldom on the impact of the collaboration in multi-disciplinary setting on the design quality.

4. Research Model

This paper will present a study on interdisciplinary collaboration carried out within the design class for Concrete Student Trophy Competition. The data was gathered from the seven former Trophies form various universities that were taking part at the competition – TU Graz, TU Innsbruck and TU Vienna. We wanted to have a look at the influence of team-composition on success in competition.
The considered characteristics of the team included team size, team composition: how many engineers, how many architects in team, demographic characteristic (male/female members).
The hypothesis was that the team members who knew each other in the past would perform better that the newly "met" teams.
From 2006 to 2012 a total of 84 student groups participated in the Concrete Student Trophy, therefore, each year on average 12 groups competed in this competition. From the participants only the data on gender, study and university are available. Based on this information we analyze the influence of group composition (study, gender, university) on the performance of the student groups (winning or not winning a price) by means of a logistic regression. For this purpose all groups winning a price (first to third and acknowledgement prices) are coded as successful groups, where as all other as unsuccessful. We decided for logistic instead of ordinal regression, and this coding in successful and unsuccessful groups as the number of prices and the existence of acknowledgement varied over the years.
Before the analyses seven groups were eliminated from the sample, five from the University of Natural Resources and Life Science, two from the University of Innsbruck and one joint team of the Vienna University of Technology and the University of Graz as these universities and constellations participated only in one year, so that inclusion would undermine representativeness.
From the remaining 76 groups that are analyzed in this study, 48 (63%) are from the Vienna University of Technology and 28 (37%) from the University of Graz. The average group size was 2,38 members (standard dev.

1,17). From the 181 participants 28 were female (15%), 153 male (85%), and 116 (64%) were architecture students while 65 (36%) studied civil engineering. Table 1 summarizes the results of the maximum likelihood logistic regression of the influence of the number of male (ma) and female (fa) architecture students and the number of male (mc) and female (fc) civil engineering students, as well as the university of student group, on the probability of success (i.e. winning a price in the Concrete Student Trophy).

Table 1. Maximum likelihood logistic regression

	Estimate	Std. Error	z value	p-value
intercept	0.5938	0.5690	1.044	0.2967
ma	0.1732	0.3532	0.490	0.6239
fa	0.3210	0.4562	0.704	0.4816
mc	- 0.9662	0.5102	- 1.894	0.0582
fc	- 1.4575	1.3435	- 1.085	0.2780
Uni	- 0.1688	0.6064	- 0.278	0.7807

Null deviance: 105.36 on 75 df
Residual deviance: 100.71 on 70 df
4 Fisher iteration steps, AIC: 112.71

The results of the logistic regression indicate that more (especially female) architects are beneficial to the probability of success, while more (especially female) civil engineers are harmful to the probability of success of a student group in the Concrete Student Trophy. University affiliation was coded as a dummy variable and indicates that student groups from the Vienna University of Technology (uni=0) achieved a higher success rate than student groups of the Vienna University of Graz (uni=1). Only the result for male civil engineers is weakly significant (p=0,0582). However, the residual deviance of the model presented in Table 1 is large and a Hosmer-Lemeshow test, a goodness of fit test for the logistic regression, indicates a poor overall fit of the model presented in Table 1, which is based on the group constitution only (X^2=-148.64, p=1.000, note: breakpoints reduced to 5 due to many ties)

Based on these first results about the low influence of group composition on group performance, we plan to develop a questionnaire to gather additional data of the participants on individual (experience, etc.) and group (acquaintance, etc.). This information should help us to gain better insights into the drivers of performance in the Concrete Student Trophy, beyond the effects of group composition analyzed in this study.

Conclusion

In this paper we presented a research on impact of team-composition on design quality, measured through success in Concrete Student Trophy competition. The findings imply that there is a weak influence of team-composition (number of architects versus number of engineers in the team or demographic team composition) on the success of the design.

The research presents a novel approach in the discussion on collaboration in design and planning – till now lot of research work has been carried on increasing of integration as well as on beneficial effects of collaborative planning in terms of optimization of time-, cost- or process quality. Little attention has been paid to identify the key performance indicators for increase of design quality, or even to determine the mechanisms or driving forces for the collaborative conceptual design and its effects on the design quality.

The interdisciplinary class and the competition present an innovative effort to promote the intensive collaboration of the architecture and structural engineering students in the earliest stages of conceptual design, requiring from both the students and the university teachers to leave the boundaries of the known and to try to act in “foreign” scope of work. This is for many a challenging experience, since the engineers need to learn to think “the unthinkable” and to dare to be creative, where as the architects need to understand the language of construction and optimization rationales. In front of all, from our observation, the process requires open-mindedness and readiness to listen at the one side, but also to talk on the same eye-level on the other. One of the teachers says in the interview: „To work in interdisciplinary team on the same eye level is not easy and it is challenging, not only for the students, but also for the teachers. When it succeeds it is more than satisfying!“

Another teacher states: „ From the teacher's perspective, it is important to communicate the meaning of the team work and cooperation in the planning. The clichés from the start such as 'the architect makes everything too complicated and too expensive' or 'the engineer has no sense for aesthetics' loose afterwards more and more on the meaning. The architects recognize in the course of the process the chance in the structure, as driver and not as barrier for the creativity. The engineers gain the insight in the work of the architects and develop the motivation to actively design themselves".

Fig. 5. Interdisciplinary workshops in design class

The study shows that the evaluation model based only on quantities – the number of people in the team and team structure is not meaningful for the project success. In our future research we will therefore focus on the influence of capabilities such as experience and acquaintance of the team members on the success in the competition. In order to gain additional information on the team performance, for 360 degrees feedback not only (subjective) self assessment of students but also interviews with the interdisciplinary teaching staff working in and with interdisciplinary teams will be carried out. In this way, the qualitative drivers for the interdisciplinary team performance in the conceptual design can be identified from both students' and teachers' perspective.

Acknowledgements

The presented research was carried out within the interdisciplinary design class at Vienna University of Technology, in cooperation with the Institute for Interdisciplinary Building Process Management, Department for Industrial Buildings and Interdisciplinary Planning, Institute of Structural Engineering, Department for Concrete Structures, Faculty of Civil Engineering, and Institute for Architecture and Design, Department for Construction Design, Faculty of Architecture and Urban Planning and Austrian Association of Cement and Concrete. The authors gratefully acknowledge the support of Prof. Christoph Achammer and C. Müller, as well of all other colleagues working on Concrete Student Trophy.

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