INTERNATIONAL DESIGN CONFERENCE - DESIGN 2016
Dubrovnik - Croatia, May 16 - 19, 2016.

IMPACT OF COLLABORATIVE SPACE ON TEAM WORK IN ENGINEERING DESIGN

M. Fechter, S. G. Kett, T. Luft and S. Wartzack

Keywords: collaboration, space design, creativity, design education

1. Motivation

The innovation of a new product is highly important for the success and growth of technology companies. Hence, these companies are highly interested in firstly creative and well qualified engineering designers with skills in various fields and secondly in an organisational culture that facilitates creativity. A creative idea does not become an innovation, until it is recognised and encouraged by the organisational environment. In this context the communication plays an essential role during the product development process. Thereby the space for communication is mostly a conventional meeting room. Those are normally equipped with one long table with chairs and projection screens, where most of the visualisation happens. Additionally often whiteboards provide a possibility to sketch information.

In the course called "Concept Development for Innovative Products" (CIP) that has been developed and introduced in Luft et al. [2013], several groups of up to five students work on a given task. The working environment provided in the last semesters is very similar to the conventional meeting room mentioned above. For the last semester a new space was planned and built. It is equipped with the intention to support the development of creative products and to enhance communication and collaboration within the team.

The objective of this contribution is to evaluate the impact of different working environments on the behaviour and the working atmosphere during group work with an educational background. How does the space design influence behaviour, the student learning and the creative output of the team work?

Therefore, first relevant literature is considered, before giving an overview of the lecture CIP. Afterwards considerations inducing the design of the space as an important factor for innovation are described. Subsequently the observations made throughout the course time are summarised, comparing classical and alternatively equipped working environments. With regard to several quantitative and non-quantitative differences, we derive first assumptions on the success of creative working environments. A short discussion of these findings leads to the conclusion that working environments actually affects product development both in a qualitative and a quantitative sight.

2. Space as a factor for innovation

As noted above, creativity and innovation are central elements for the corporate success [Shalley et al. 2004]. In a study conducted by IBM with more than 1500 CEOs from all over the world, creativity was chosen as the most important leadership characteristic, prior to integrity and global thinking [Berman 2010]. It is also stated that it is not expedient to have isolated creative individuals in a department, but to seed creativity over the entire organisation. The CEOs point out that the stage has to be set, so the organisation can evolve to be a catalyst for creativity.

To clarify the understanding of the diversely used terms creativity and innovation, precise definitions from literature are introduced in the following. The understanding of the terms in this contribution follows the definitions from Amabile [1988], where the definition of creativity is based on products: "creativity is the production of novel and useful ideas by an individual or small group of individuals working together". Those ideas are the fundamental elements, where innovation can arise from: "Organizational innovation is the successful implementation of creative ideas within an organization" [Amabile 1988]. Summarising, creativity refers to the development of a novel, potentially beneficial idea, and is necessary for innovation; so if a novel idea is implemented in the organisation successfully, it is considered to be an innovation [Shalley et al. 2004].

According to the componential theory of creativity, the ability of an individual to produce creative work is influenced by four components [Amabile and Pillemer 2012]. Three of them are within-individual components: the individual has to have 1. knowledge, expertise, technical skills, intelligence, and talent in the particular domain, 2. high skill in creative thinking and 3. an intrinsic motivation because of interest, enjoyment, satisfaction, or challenge of the work itself [Amabile and Pillemer 2012]. The fourth component is an environment - primarily the social environment - that supports creativity. Environmental factors can affect both the extrinsic and the intrinsic motivation, with positive or negative impact. In this contribution the focus is on the environment and, in detail, on those elements of a collaborative space that encourage creativity.

2.1 Collaborative space and its effect on student learning

Brooks [2011] describes an experiment, where two identical classes were taught by the same instructor using identical resources, like e.g. course materials and exams, whereas the formal learning environment differs considerably between the two sections. Measured by grades, the learning results of the group in the technologically enhanced environment conducive to active learning techniques were noticeable higher than those of the group in the traditional classroom [Brooks 2011]. Possible explanations for this could be either space or pedagogy. A subsequent study shows that the formal classroom space shapes the behaviour of instructors and students who work within them [Brooks 2012]. Concerning the classroom activities, for example, there was an enormous difference in the frequency of class discussions occurrence. Summarising, the physical constraints and the possibilities provided by the environment influence the behaviour and as a consequence the creativity of persons within it. In contrast to Brooks [2012], the pedagogy of the CIP course (described in more detail in section 3.1) was planned to be oriented towards lecture on demand and not a lecturer standing in front of the class.

Jankowska and Atlay [2008] focus on the question, which element of a creative space influences the students' learning and their creative capacity. The room that was used in their study - the "Creative Space" facility - includes large white, writable walls, laptops with software for brainstorming and other activities. Casters on tables, couches and mobile whiteboards ensure flexibility in rearranging space for different usage scenarios [Doorley and Witthoft 2012]. If the tables and stools can be moved easily, forming subgroups of a team can be done quickly [Streitz et al. 1999]. Another frequently noticed environmental condition is the ownership of a space during some time period achieved through personalisation. Leurs et al. [2013] observed an engaged and enthusiastic team that personalised their space through hanging up pictures, placing plants or other personal belongings. Furthermore they had the possibility to stay at the place open-ended.

Derived from the aspects in this chapter, we will introduce the design of our creative collaboration space (CCS) in section 3.2.

3. The lecture of Concept Development for Innovative Products

Prior to the elicitation of the advantages and potential benefits of the new working environment in chapter 4, the structure and peculiarities of this course will be introduced. Subsequently the design of the space will be introduced in this chapter.

3.1 The structure, content and course of the lecture

CIP is part of the design engineering curriculum since the summer term 2012. This lecture can be selected by students of five master degree programmes of the Faculty of Engineering: Mechanical Engineering, Industrial Engineering, International Production Engineering and Management, Mechatronics as well as Medical Engineering. This advanced course aims at training master students in various aspects of integrated engineering design. Participation in this course requires the ability to independently use various methods learned from courses like "Technical Product Design", "Methodological and Computer Aided Design" and "Integrated Product Development". Therefore these courses are prerequisites for taking part in the elective subject CIP. The students deduce knowledge e.g. about the development and design of technical products and systems from ideas to concepts (in particular in the early stages of the product development process). Therefore, the lecture is targeted to students with basic knowledge about different product development methods.
In CIP the students are confronted with a vague task or problem situation and are asked to develop and to present concepts for innovative products in teams of five. In this regard, CIP is a combination of three teaching and learning approaches, which are the presentation of the working progress and project status by student teams, the subsequent discussion between supervisors and students and the presentation of lectures on demand by the supervisors with the help of a method catalogue (Figure 1). These three approaches are explained in the following subsections and in detail in [Luft et al. 2013].

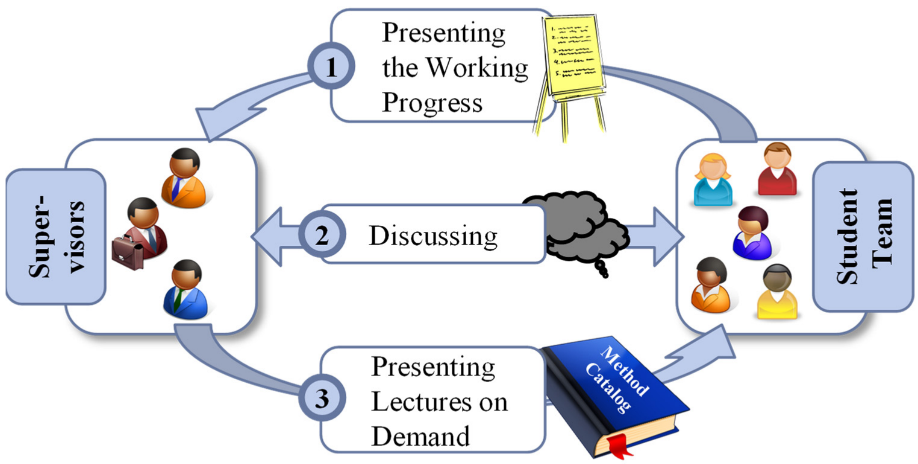

Figure 1. The three teaching and study approaches

Presenting the working progress

Besides the professor, two research assistants are attending the working meeting of the student teams. First of all, the supervisors get informed on the achieved working progress from the team. So, the students have to provide information about the current state of their ideas and concepts. As a consequence, the students reflect their work critically and think about reasonable next steps. Moreover, the supervisors get a good impression about the learning progress and as a result, an active monitoring of the students' work is possible.

Discussing

Subsequently, the educational staff asks critical questions to each student team and discusses not only their ideas as well as specific technical, economical and socio-cultural issues, but also how to proceed. Among others, typical questions are: What technical features are very important for the product to be developed? What sales volume is necessary for a certain turnover? Which customers or customer groups should be targeted? What are their specific requirements and how should they be addressed by the product?

Lectures on demand

During the visit of the supervisors, the students have the opportunity to ask for so called lectures on demand about specific topics and methods. On request, the supervisors give a short lecture on a particular method which may be applied by the students in their future work. The supervisors use a comprehensive method catalogue which has been developed particularly for this lecture [Luft et al. 2013]. This method catalogue includes potentially helpful methods that are important in product development (e.g. Morphological Analysis, QFD, Kano Model, Target Costing).

3.2 Setting the stage for creativity

As mentioned, the aim for this contribution is to examine the role of space during team work within CIP. In this section, some general information regarding the room is given, before the design and the equipment of the space is explained in more detail.

To set the stage for creativity in the "creative collaboration space" (CCS), a virtual reality (VR) system was supplemented with additional furniture and equipment. The establishment of the CCS within the VR lab was beneficial due to the availability of extra space (about 25 m²) and the possibility to visualise product data immersively.

The space was designed for the team work of four to seven students. There are different working areas, e.g. for active team work or for relaxing. Unlike conventional classroom setups, there is no orientation towards a whiteboard or projection surface (see Figure 3, left).

As Jankowska and Atlay [2008] show, people sometimes fear that disclosing an idea or thought can lead to laughs and a lack of understanding in the group. This is an example where extrinsic motivation or extrinsic constraints, like the threat of a bad evaluation of the communicated idea, can hinder creativity. Consequently, enabling an open minded dialogue and discussion atmosphere is essential for enhancing creativity. In this case, it is very important that every member of the team feels like communicating at eye-level with the others. A "special" seating position like the head of the table was avoided through using a large square table. In a conventional lecture setting in a traditional class or meeting room, the roles are clearly defined: the person giving the lecture is standing in front of the audience and the attention is targeted on the whiteboard or slides. In this setting the students are in a passive, "consuming" mode. To get everybody up on the same level, stools were used (see Figure 2, left), so the standing individual talking about an idea or giving a lecture on demand is on the same height like the listeners [Doorley and Witthoft 2012]. Additionally, the stools imply a more active behaviour, only through the fact that standing up to do something from this high seating position is much easier, than doing the same from a comfortable wing chair. As mentioned above, there is no orientation towards a point of interest within the room.

Communicating an idea coming from an individual can be a starting point for innovation. Only a known idea can grow or be an impulse for further development within a team. Due to this it is essential to provide possibilities simplifying and facilitating this initial process. The CCS was planned to enable a wide array of options for that. One usually unused possibility is the surrounding walls that potentially provide lots of space for visualising and capturing ideas. So we added wall-scale dry-erase writing surfaces made of melamine coated chipboards (see Figure 2, right). Writable walls support facets like playfulness and humour that positively influence creative thinking [Jankowska and Atlay 2008]. Besides the fixed wall-scale whiteboards there are also movable ones that may be used during a discussion session next to the square table. A roll of drawing paper and magnetic tape was added to the writeable walls, so the team can have a discussion session at the table, writing onto the paper and then pin the sketches and notes to the wall. For visualising digital product data or information from the internet, the power wall can be used as a large projection surface. To enhance flexibility, a mobile projector can be freely placed, so every surface (e. g. writable walls) can serve as a projection surface.

As described before, the stools are explicitly intended for active phases during collaboration. The small plastic sitting surfaces are not the most comfortable seating option. It is not comfortable for long seated sessions, but for shorter active sessions indeed, where people stand up and come back continuously. The students are thus stimulated for active participation. Furthermore, the space adaptive to more than one working situation through nonprescriptive seating options [Doorley and Witthoft 2012]. In contrast to the bar stools, there is also a meeting area with more comfortable, lower stools and a couch, depicted in the middle of Figure 2. This is intended for more relaxed and intimate conversations, whereas the mobile whiteboards may serve for taking notes of arising ideas.

In a space with expensive and elegant materials, students may be hindered in their activities because of fearing to break or scratch something. We planned to use rough and stable furniture and equipment that seems to communicate: "I do not need to be handled with too much care." The table top for example is a transparently painted, 21 mm thick sheet of plywood with sufficient stiffness to withstand a lot of weight. If it is touched with fingertips, one can feel the wooden texture. The wall mounted, dry-erase surface has more than ten square metres in size and is made of melamine coated chipboard that costs only a fractional amount of money compared to whiteboard paint or conventional whiteboards. The edges are not lacquered and the rough material of the chipboards is visible. Common board markers are used to write on the walls and the paint can be removed with whiteboard cleaner and a rag. The design of the flexible stools (see Figure 2, middle and right) is strongly inspired from the "Flip Stool" [Doorley and Witthoft 2012]. They are made out of 28 mm plywood and can be used both as a bar stool (right photo) or as a bench. Compared to the Flip Stool, the functionality was extended through adding a recess that empowers the stool to be a pedestal for a whiteboard. A sheet of chipboard can be inserted to get a moveable whiteboard (see Figure 2, middle).

Figure 2. Stools around a square table (left); couch and stools that can be used in standing or low position (middle); large writeable walls (right)

During the semester, the CCS is dedicated to a team of five students attending the CIP course, giving them the possibility to personalise the space. Creating a sense of belonging is very important in an open and collaborative environment, because it makes an individual feel less vulnerable [Doorley and Witthoft 2012]. Intending to increase this sense of ownership, some adjustable features were integrated. The team was encouraged to arrange the furniture and equipment as they liked it best. The possibility to move all the items in the CCS should signify openness towards change and consequently also towards new thoughts and ideas. Music can distract the mind if it is too loud, but listening to one's favourite song can also create a sense of belonging and distract the mind in a positive way. So the space was equipped with a movable loudspeaker, easily connectable to a mobile phone. Another resulting advantage of designated space is the freedom of not having to clean the writable walls or to put away every idea captured on a sheet of paper at the end of each session. Everything is still there until the return of the team in the following days and past information or ideas can be taken up more easily. An available refrigerator can be equipped with the favourite drink and a coffee machine ensures the supply of caffeine. The table football is intended for short time mind distraction, signifying fun and feeling well is wanted. It must be noted that there is no space for concentrated individual work in the room. Students are encouraged to go to a student computer pool room located near by the CCS, if they have a need for a quieter, more private single working environment.

4. Case study - conventional vs. advanced collaborative space

In this study under consideration, the objective is to evaluate the relation between different working environments and the social behaviour or the climate in groups. Investigations regarding the impact of different interior designs and equipment on group creativity in lectures may thus give valuable advice

how to design space for creative output. Therefore we focus on different kinds of parameters that indicate the nature of social behaviour and working results and analyse them later on.
In the following, we describe the observations made throughout the project's term. Before starting the case study, the creativity of each test person has been assessed to ensure independent observations (section 4.2). Based on the findings throughout the case study (section 4.3), both subjective and objective parameters to define the success of the CSS are differentiated (section 4.4). Finally, the discussion of possible limitations both in evaluation criteria as well as the concept itself and future potential conclude this chapter.

4.1 Study design

As stated in section 3.1 the core task of CIP is the treatment of a very open problem solution process in the concept stage. The opportunity to participate in this course depended on prior experience in product development e. g. relevant courses or internships. The test persons in the current case study were master students both in Mechanical Engineering (9) and in Industrial Engineering (4) and divided into three project teams with 4 to 5 members each. One of the teams (team CCS) was let into the concept room whereas the two others (team NC1 and team NC2, where NC stands for normal classroom) had well equipped modern classrooms (see Figure 3). It was clearly communicated that both environments represent adequate working areas, to prevent the students from feeling disadvantaged because of not being a participant in the CCS. The duration was scheduled for around 4 months with at least one meeting per week (see chapter 3.1). As they all had more or less the same educational background and therefore an adequate basis of knowledge, the competitive situation in between the teams was well communicated by the lecturers.

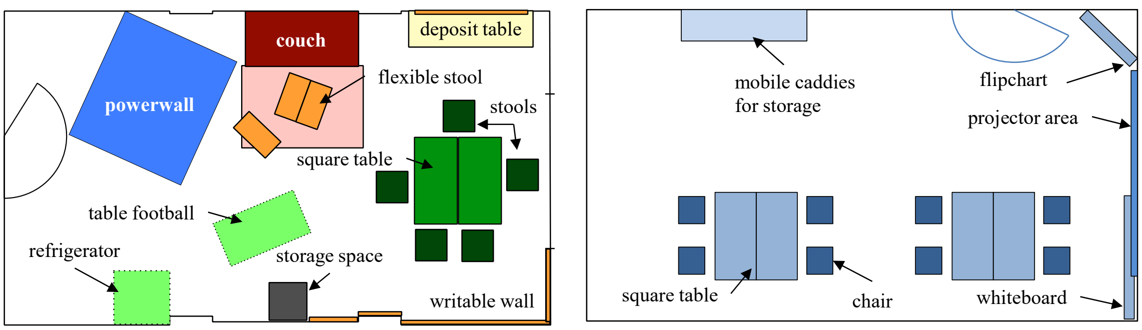

Figure 3. Schematic layout and equipment of the two types of classrooms: CSS (left) and standard classroom (right)

4.2 Measuring creativity

As stated earlier, creativity plays a major role in engineering design, regarding problem solving in particular. Consequently, the targeted encouragement of creativity is important in engineering design education. Within the present course, one objective is to unlock the students' creative potential and to develop their creative competence. Therefore, the contribution of personal creativity to group idea development is particularly examined. The nature of creativity is often described as a combination of originality and task appropriateness within a particular social-cultural-historical context [Beghetto 2013]. With regard to the objective of evaluating the environmental influence, we have to distinct between group creativity and individual creativity. If the members from the three teams would have an equal individual creativity, we could conclude that this is no factor that entails deviating group creativity. During the workshops, the personal creativity of each participant was assessed using a verbal creativity test [Schoppe 1975]. This quantitative method consciously reduces creativity to verbal communication skills to enable approximate comparability and is thus sufficient for first appraisals. It is based on six production systems, e. g. the human association abilities or idea creation and refers to different material classes (verbal, figural, numerical). [Schoppe 1975] The data was collected and evaluated by a written survey in a supervised session. Figure 4 represents the results. It states that the students from team CCS don't have a remarkable individual creativity on comparison to the rest. According to these findings, we conclude that there are no tremendously unbalanced preconditions that may lead to misinterpretations of the outcome.

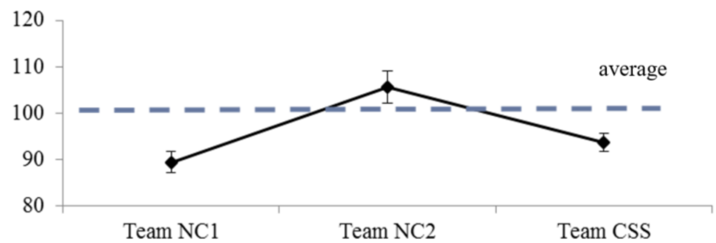

Figure 4. Test results in VKT with standard deviation

4.3 Findings

In the following, the main differences within the test teams are briefly summarized. Therefore, we examine the social behaviour and team organisation, the treatment of methods and tools and the surrounding and space interaction. Within this chapter, the nature of ideas and the value of the output are also assessed. The investigated parameters were both of objective and subjective nature. As objective parameters can be measured instantly (e. g. amount of time or methods used), subjective parameters were indirectly measured using auxiliary means (e. g. ordinal scales for mood objectification).

4.3.1 Social behaviour and team organisation

Teamwork and communication are valuable factors in product development processes [Ehrlenspiel and Meerkamm 2009]. Within the three teams, we therefore assess the parameters frequency, duration, nature of meetings and social and emotional behaviour to evaluate the group interaction. Whereas the two teams in the common classrooms meet once a week as obligatory and foreseen, the CSS team meets several times, both in formal and leisure intent (e.g. for playing table football). It must be noted that all teams had the possibility to use their classroom for additional team meetings.

In comparison with the teams NC1 and NC2, the social emotional behaviour of team CCS was thus much more natural and open. They also show high volatility in organising spontaneous meetings. There is reason to assume that social motives beyond the given task play a role and form a unique kind of team spirit. The conversations within the meetings are of high intensity and indicate enhanced team thinking. Social interaction is enforced and provokes emotional involvement of each single person in the team. The individual potentials may be better released and team creativity may thus become more multifaceted.

4.3.2 Methods and tools

Within the lecture, one scope is the appropriate application of methods and tools that support the early concept phase in product development processes. The choice of which methods to take was left open to the students. The set of standard methods like morphological boxes was used by every team, but differed in their specific application depth. In our observations, we note that in the CCS, the team critically examined each method and questioned each step before and whilst applying it for their purpose. Furthermore, the iterations throughout the application of methods were of higher rate. In a sum, the respective team used about 12-15 different methods in about 4-5 iterations, whereas the other teams used about 8 different methods in about 2-3 iterations in average.

4.3.3 Surrounding and space interaction

Regarding the usage behaviour and the perception of the surrounding to find, discuss and value solutions, differences between the teams are distinguished. With respect to the two teams remaining in classical rooms, the third team enhances their facilities in a fundamental way. They changed their perception of surrounding, e.g. walls to be written on and thinks of conscious misappropriation of everyday things (e.g. using pencils as bending beams). Even more, we state an extension of these aids by adding private items such as a small wooden figure, allowing the conduction of simple studies on the mobility of the human body. Even though there are also tools given such as whiteboards or presentation tools, most of these tools remained unused in the other two teams (see differences in Figure 5). In the same row, the physical activity, like the time standing next to the writable wall while discussing a problem or the frequency of movements between stool and writable wall, of all teams was observed to be much higher in the CCS.

Figure 5. Social interaction and the integration/adaptation of environment: regular classrooms with high passive behaviour (left) vs. CCS enabling high activeness and both social and environmental interaction (middle and right)

4.3.4 Nature of ideas, processes and value of output

In the regular classrooms, the students' ideas and working processes were close to common solutions and routines. Though they all followed up a project plan, roughly given by the lecturers, the team in the CCS soon began to experiment with its resources. The thoughts and ideas became more exalted and the problem space was more focused and concrete earlier in the process than it was in the comparative teams. There was more a "trial and error" spirit throughout the work time. In a sum, both the amount and the depth of originality of the ideas were observed to be higher. In contrast to this, the maturation and reflection of the concept seemed rather similar throughout all the teams.

4.4 Discussion and conclusion

Measuring creativity of an idea or of a team member is a challenging task. Several researchers state the difficulty of creativity measurement [Beghetto 2013]; it is based on focusing on certain aspects that may influence one's creativity. In studies the measurement mostly happens through ratings given by an individual who is believed to have advanced knowledge within the domain of interest [Shalley et al. 2004]. As described in chapter 2, the componential theory of creativity indicates that the fourth component - the environment - has influence on the creativity. Now that several differences in group work were observed and measured during the classes, possible implications on increased creativity are presented in the following. Additionally we want to point out which element or boundary condition of the space (e. g. furniture or availability) may be responsible for the observed differences between the two teaching spaces. At the end of this section, selected comments and improvement suggestions made by the students are discussed.

The difference between frequency and quantity of team meetings indicates a higher intrinsic motivation of the CCS team members. This may result from the enjoyment during group work or the challenge of and interest in generating ideas and concepts together. Furthermore, the fact that the CCS team meets with leisure intent shows that the members feel well in the team and the space. The atmosphere within the team is relaxed, interested and open minded. This enhances the willingness to communicate ideas that look daring at first sight. This openness is an essential prerequisite for creativity.

Additionally we observed that team CCS applied the methods of early phases in product development in greater depth. Moreover, they often firstly critically examined the methods themselves before applying them to their respective task. It might be reasonably assumed that the learning result is thus of greater value compared to teams that applied the methods and tools more superficially.

In the CCS we could observe a personalisation of space. Already at the beginning of the term, team CCS immediately installed personal equipment like a small wooden human model (see Figure 2, right) that was helpful to find concepts for the given task. Another noticeable difference described above is the number and the amount of time the whiteboard respectively the writable wall was used. This may be influenced by the rougher and less precious appearance of the CCS's interior and the less comfortable stools, which lowers the barrier to get active and e.g. use the writable wall to sketch an idea. Thereby a difference in communication scenario arises, as well as in public documentation of the ideas and thoughts within the team. This may have positive impact onto the teams innovative output.
In interviews conducted at the end of the term, the students of team CCS had the chance to comment on the space itself and also on potential for improvement. One opinion all team members shared was that the wish for more writable wall space (currently about ten square meters) and especially more continuously writable space that is not interrupted by gaps between two melamine coated chipboards. The possibility to stop working on an idea and continuing it later on without having to put away stuff and clean the writable walls was praised. Furthermore, one student claimed for more comfortable seating options, because there are not enough of them for five persons. Another participant had the idea to create a cosier atmosphere through appropriate illumination. The students from the CCS also know the classroom of the teams NC1 and NC2 and were asked for differences coming to their mind. They commented that the CCS is not that sterile compared to the other classrooms. All in all, the level of detail in the CCS team's feedback was rather high. This may lead to the conclusion that the appropriateness of the CCS was already widely agreed.
Subsuming we clearly see differences between the classroom configurations. On the other side, it is hard to prove a relation between the design of the CCS and higher value of the output resulting from group work in general. The significance suffers from the low extent of the study, because CIP was offered only once since the CCS was established, and from the general uncertainty of evaluating creativity. Repeating the course with a larger number of student teams that use the CCS in the future will relativise this drawback.
The fact that team CCS applied methods of early phases in the product development process in greater depth indicates that the space design extends the discussion and therefore also the exchange of knowledge and expertise in the particular domain. According to Amabile and Pillemer [2012] this enhances one of the within-individual components that is necessary for creativity. Finally we conclude from observations that the classroom activities, e.g. the amount of time discussing in front of the writable surface, differed noticeably. Due to the fact that the content of the course, the lecturers and the pedagogy was identical between teams, there is a link between the difference in classroom activities and the design of the collaborative space. The results indicate noteworthy differences that can help to positively influence learning and creativity in future lectures.

5. Summary and outlook

The idea presented in this paper is to observe and measure the effect of space onto the behaviour and the creative outcome of group work with an educational background. Therefore, the creative collaboration space (CCS) was planned and realised for the summer term 2015. It is intended for a team of four to seven students that conjointly work on one task. In the elective subject called "Concept Development for Innovative Products" (CIP), which focuses on the conceptual design stage in early product development phases, the students generate ideas and develop innovative concepts. During the summer term, three competitive teams worked on the same task, one of them in the CCS and two in conventional classrooms.
In this contribution we described how and why the space was designed. On the basis of observations and measurements made by the lecturers during the term, differences between the two classroom configurations have been detected that support the findings of Brooks [2012]. For instance, the number of meetings besides the obligatory weekly lesson or the intensity of the application of tools and methods during the concept design phase diverges for the benefit of the CSS. This induces an enhancement of the students learning through the CSS. Subsequently we analysed the effects of the CCS space design onto the nature, dynamic and atmosphere of collaborative work.

For the future, we plan to enhance the CCS through the integration of more writable surfaces and we want to achieve more flexibility in placing the furniture through casters on tables and the couch. In an additional study the observations from not only one, but several courses should strengthen and broaden the findings made in this contribution. Additionally we plan to capture videos of the classes with and without lecturers, to get more quantitative values of the classroom activities.

References

Amabile, T. M., "A model of creativity and innovation in organizations", Research in organizational behavior, Vol.10, No.1, 1988, pp. 123-167.

Amabile, T. M., Pillemer, J., "Perspectives on the Social Psychology of Creativity", The Journal of Creative Behavior, Vol.46, No.1, 2012, pp. 3-15.

Beghetto, R. A., "Killing ideas softly? The promise and perils of creativity in the classroom", Information Age Publishing Inc., Charlotte, USA, 2013.

Berman, S., "Capitalizing on Complexity: Insights from the Global Chief Executive Officer Study", Report from IBM Business Services, Somers, USA, 2010.

Brooks, D. C., "Space and consequences: The impact of different formal learning spaces on instructor and student behavior", Journal of Learning Spaces, Vol.1, No.2, 2012.

Brooks, D. C., "Space matters: The impact of formal learning environments on student learning", British Journal of Educational Technology, Vol.42, No.5, 2011, pp. 719-726.

Doorley, S., Witthoft, S., "Make Space: How to Set the Stage for Creative Collaboration", John Wiley & Sons Inc., New York, USA, 2012.

Ehrlenspiel, K., Meerkamm, H., "Integrierte Produktentwicklung. Denkabläufe, Methodeneinsatz, Zusammenarbeit", Hanser Munich, 2013.

Jankowska, M., Atlay, M., "Use of creative space in enhancing students' engagement", Innovations in Education and Teaching International, Vol.45, No.3, 2008, pp. 271-279.

Leurs, B., Schelling, J., Mulder, I., "Make space, make place, make sense", Proceedings of E&PDE 2013, the 15th International Conference on Engineering and Product Design Education, Lawlor, J., Reilly, G., Simpson, R., Ring, M., Kovacevic, A., McGrath, M., Ion, W., Tormey, D., Bohemia, E., McMahon, C., Parkinson, B. (Eds.), Dublin, Ireland, 2013, pp. 844-849.

Luft, T., Schleich, B., Wartzack, S., "Concept Development for Innovative Products - A Challenge for Engineering Design Education", Proceedings of the 19th International Conference on Engineering Design 2013, Lindemann, U., Venkataraman, S., Kim, Y. S., Ion, W., Malqvist, Y. (Eds.), Seoul, Korea, 2013, pp. 105-114.

Schoppe, K.-J., "Verbaler Kreativitäts-Test-VKT: ein Verfahren zur Erfassung verbal-produktiver Kreativitätsmerkmale", Verlag für Psychologie Hogrefe, Göttingen, Germany, 1975.

Shalley, C. E., Zhou, J., Oldham, G. R., "The Effects of Personal and Contextual Characteristics on Creativity: Where Should We Go from Here?", Journal of Management, Vol.30, No.6, 2004, pp. 933-958.

Streitz, N. A., Geißler, J., Holmer, T., Konomi, S., Müller-Tomfelde, C., Reischl, W., Rexroth, P., Seitz, P., Steinmetz, R., "i-LAND: An Interactive Landscape for Creativity and Innovation", Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '99), ACM Press, New York, USA, 1999, pp. 120-127.

Verein Deutscher Ingenieure (VDI), "VDI Ingenieurstudie", Studie der VDI Wissensforum GmbH, Düsseldorf, 2008.

Marius Fechter, M.Sc.
Friedrich-Alexander-Universität Erlangen-Nürnberg, Mechanical Engineering
Martensstraße 9, 91058 Erlangen, Germany
Email: fechter@mfk.fau.de