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Designing Innovation: Prototypes and Team Performance in Design Thinking

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Abstract: This study investigates design thinking innovation teams working on three different innovation tasks: business model innovation, service innovation, and product innovation. Each task involves the generation of many prototypes, one of which needs to be selected as the final prototype. Further, one of the teams collaborated through virtual collaboration. By measuring both subjective and objective performances of the teams, we compared the different innovation tasks and their impact on design thinking teams. Our preliminary study shows that while the generation of many prototypes indeed seems to support the selection of the best final prototype, it is mostly the team process which impacts the quantity of all and quality of the final prototype. Especially the virtually cooperating team working on a service innovation task, experienced major difficulties in the process, while we can report that the business model innovation team generated the most prototypes while working in a rather harmonious team.

Keywords: Design Thinking; Innovation; Prototypes; Innovation Teams; Performance Measures

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1 Problem: What specific problem does the submission focus on?

The study focuses on design thinking teams and assesses their performance when working on product, service and business model innovation tasks by measuring both subjective and objective process and outcome variables.

Design Thinking is an innovation approach that reached much attention, from researchers and practitioners as well (Cross, 2001; Cross *et al.*, 1992; Markus *et al.*, 2002). Design thinking research can be situated in the design-science research, which is one of the research paradigms of the information systems discipline (Hevner et al. 2004). The design science paradigm seeks to extend the boundaries of human and organizational capabilities by creating and shaping new and innovative artefacts (Hevner, 2004), which address unsolved problems. Knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artefact (Hevner *et al.*, 2004). The design process is twofold, the first phase being a sequence of expert activities to produce an innovative design artefact. The second phase is the evaluation of the artefact, which then provides feedback information and a better understanding of the problem, meant to improve both the quality of the artefact and of the design process (March & Smith, 1995). Building and evaluating the artefact takes place in iterative "build-and-evaluate loops" (Markus *et al.*, 2002). Cross (2001) defines design science as referring "to that body of work which attempts to improve our understanding of design through 'scientific' (i.e., systematic, reliable) methods of investigation."

The approach is especially promising and much recommended to support innovation teams in organizations (Sutton & Hargadon, 1996). In order to understand how teams work in the design thinking innovation process with different innovation challenges, namely product, service and business model innovation, we provide a preliminary study by analysing teamwork process and outcome by measuring both subjective and objective performance in design thinking teams. Performance assessment of innovation projects is a central issue in innovation management research (Blindenbach-Driessen *et al.*, 2010), and especially the impact of teamwork on success (M. Hoegl & Gemuenden, 2001). However, design thinking as applied in practice, has not yet been sufficiently analysed in this regard.

2 Current understanding: What is known about this problem?

New approaches such as design thinking have received much attention in recent innovation research and practice (Boland & Collopy, 2004; Grots & Pratschke, 2009; Sato, 2009) in order to enable idea generation and selection (Girotra *et al.*, 2010) and to reduce the uncertainty innovation teams face to a large degree (Sicotte & Langley, 2000).

Design Thinking Research

Design thinking is a human-centred innovation method accompanied by a structured process in order to raise the probability of innovation success (Dym et al., 2005; Skogstad, 2009; Vetterli, et al., 2011). Design thinking as applied in our context has its roots in mechanical engineering at Stanford University, and is most often applied for product innovation. The main elements of the method are in this order: Needfinding, ideation, prototyping, testing and redesigning (Nussbaum et al. 2005). Typically, design thinking starts with a human centered innovation challenge, or problem statement, such as creating "active packaging". Human centricity is understood as a strong focus to underlying human needs, which are most of the time unarticulated. The elements are implemented by pursuing methodologically and timely defined milestones to ensure the delivery of many prototypes during the project, and in the end the final prototype. Further, the milestones are defined along specific prototype requirements: Critical Function Prototype; Dark Horse Prototype, Functional Prototype and Final Prototype (Skogstad, 2009). Whereas the first two milestones, Critical Functional Prototypes and Dark Horse Prototypes, are meant to foster divergent thinking in the team, the milestones Functional Prototypes and Final Prototypes support converging thinking.

The main outputs of design thinking are developed and tested prototypes. Terwiesch & Loch (2004) see the evolution of prototypes as a learning mechanism in the context of customized design. Prototypes are tangible ideas, which are more and more refined in the course of the process. While in the divergent phase at the beginning of the design thinking process multiple prototypes are developed, the convergent second phase leads the team to focus on finishing one high resolution prototype (Ulrich & Eppinger, 1994).

Team Innovation Measures

Research on innovation teams focusses on both *subjective and objective performance measures* (Girotra et al., 2010).

Objective idea quality measures are based on research on idea generation effectiveness and encompass both idea quantity and quality. The quantity of the idea generation method is identified by simply counting the total number of ideas generated per team. Research argues that by generating many ideas, teams are more likely to generate good ideas (Diehl & Stroebe, 1987; Simonton, 1999). However, researchers have for most parts moved away from counting the total number of ideas to focus mostly on the examination of the average idea quality as well as the quality of the best idea. Girotra and colleagues (2010) rightly point out that it is further necessary to measure if the group is able to select the best idea. In order to assess what the best idea of a group is, many researchers have suggested independent judges to assess the quality of generated ideas (Amabile, 1982; Amabile *et al.*, 1996; Connolly et al., 1990; Girotra et al., 2010; Kramer et al., 1997).

Different operationalization of quality are used in research projects (Faure, 2004). Most commonly, idea quality is defined as a combination of originality and feasibility (Diehl & Stroebe, 1987). Rietzschel, Nijstad and Stroebe (2010: 48) define a quality idea as "both highly original (or unusual) and highly feasible (or useful)". Girotra and colleagues (2010: 593) have suggested broadening the measure based on extreme value theory, which proposes that a group can discern good ideas from bad ideas. The expected quality of the best ideas is driven by the number of ideas generated, the average idea quality, and the variance of the quality distribution (Girotra et al., 2010: 593). The quality measure used in this study reflects the multidimensions of the measure, consisting of 7 different metrics in total: Technical feasibility, novelty, specificity, demand, overall value, creativity, and value for the target group. The first five metrics have been established and verified by Girotra and colleagues (2010); the final two metrics are derived from the assessment of Kramer (1997). The scale was measured on a ten-point Likert scale ranging from very poor to very good.

The subjective performance measures in innovation teams used in this study are derived from multiple scales. Research has found that teamwork quality (TWQ) is positively related to team performance, as well as success of team members (M. Hoegl & Gemuenden, 2001). Hoegl and Gemuenden (2006) developed and tested a comprehensive TWQ concept, which allows for perceived measure of performance and member satisfaction. Specifically, teamwork quality measures (communication, coordination, balance of contributions, mutual support, effort and cohesion) are combined with team performance measures (effectiveness and efficiency) and personal success measures (work satisfaction and learning). While Hoegl and Gemuenden (2001) differentiate between the effects on managers, team leaders and team members, and report considerable differences regarding the performance ratings, we focus solely on the team as a whole.

Further, research has found that team reflexivity is positively related to effectiveness by supporting the teams in finding better solutions to the problems they are facing (Hoegl & Parboteeah, 2006). We use the scale of Hoegl and Parboteeah (2006) to measure team reflexivity in innovation teams, which is based on West's (1996) work on team reflexivity and effectiveness. Hoegl and Parboteeah (2006) add the dimensions of social skills and project management skills as determinants of reflexivity to the original scale. Measuring team reflexivity may offer powerful insights into areas where innovation teams can be influenced in order to enhance their performance; therefore, it is important to include this measure in our study of examining design thinking innovation team performance.

Anderson and West (1998) suggest the team climate inventory (TCI) to identify factors for innovativeness of teams based on team climate. In our study, we used two facet-specific climate scales of vision (all 12 items) and team participation (9 items) of the original scale.

Finally, we use the scale developed by Blindenbach-Driessen and colleagues (2010) to measure the overall performance of design thinking innovation teams. Performance is defined as a combination of operational, i.e. technical performance and captured knowledge, and product performance, i.e. customer satisfaction and competitive advantage of the developed innovation. Initially, the scale has been developed by the authors to measure the performance of new product and service innovation projects. We apply the scale to measure the performance of a design thinking business model innovation project as well.

3 Research question: What is the submission's goal?

Innovation with the design thinking approach is of much interest for researchers and practitioners (Cross, 2001; Cross *et al.*, 1992; Markus *et al.*, 2002). Further, research on the performance assessment of innovation teams has progressed substantially, as well as on innovation tasks (Shah *et al.*, 2000; Shah *et al.*, 2003), for example product development (Hoegl & Parboteeah, 2006), service innovation (Blindenbach-Driessen et al., 2010), and business model innovation (Eppler, 2011). So far, the impact of design thinking on different innovation tasks has not yet been sufficiently assessed. Specifically, we are interested in gaining a better understanding of which impact team metrics have in

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design thinking innovation teams, working on product, service and business model innovation tasks, on both outcome and process. Our research question is:

RQ: Does a different innovation task influence the objective and subjective performance of design thinking teams regarding outcome and process?

4 Design/methodology/approach: How was the study/work executed?

While research acknowledged the importance of generating and selecting the best idea from innovation processes (Girotra et al., 2010), there is limited evidence on our research question in the existing literature. Thus, we choose an exploratory, data-rich research design to answer our research question (Eisenhardt & Graebner, 2007). Our study is concerned with innovation teams which solve business model, service and product innovation tasks using the design thinking innovation methodology. The final outcome of a design thinking innovation project is one highly tangible prototype. This final prototype has been developed by building, refining, and dropping many prototypes before finally selecting one prototype. It is critical to maintain the real-life context of design thinking innovation in teams, since we do not know ex ante how the teams will perform. A multiple exploratory case study design fulfils these requirements (Eisenhardt & Graebner, 2007; Yin, 2003).

The context of this research was a graduate course at a Swiss University, which focuses on applying design thinking on a real-life innovation challenge, offered by industry partners. The industry partners are from different industries and provide product, service and business model innovation challenges for a 10-month working period before receiving the final prototype as final deliverable out of the project. The design teams consist of graduate students with multidisciplinary backgrounds, as well as prior working experience. The class of 2010/2011 consisted of seven teams with three students each. The design thinking teams started in September 2010 and graduated from the course in July 2011 with no breaks in between. The teams passed the different milestones, described in section 2, in order to finish their projects. During this time the teams went through weekly coaching from experts concerning the methodology and developed their prototypes within intensive teamwork.

In depth, we have analyzed three different teams with three different innovation challenges: Product, service and business model innovation challenges. The teams are anomymized and labelled as follows: Mars (Business model innovation team), Venus (Service innovation team) and Mercury (Product innovation team). The data collection was based on the questionnaire outlined in section 2 to gain more insights regarding performances of each team over the different stages. After every main milestone, every team member received the questionnaire via e-mail and filled it out through an online-platform. Finally, the results of the questionnaire were screened after a descriptive data analysis on team level as well within a cross-team analysis. The final prototypes were assessed and ranked by applying perceived and quality measures provided by team members as well as independent industry experts. Additionally, the team members reflected their progress and outputs on an individually and as a team. The findings were coded and reviewed independently. For a comprehensive overview on both subjective and objective measures, in addition to the quality measures of the study, also the total amount of prototypes were considered generated by each team. .

5 Findings: What are the main outcomes?

Girotra and colleagues (2010) highlighted the importance of not only generating good ideas, but enabling teams to select the best idea. Design thinking leads teams to develop as many prototypes as possible in the diverging phase, followed by consolidating their ideas and combine most successful elements of prototypes in the converging phase. At the end one single best prototype is developed.

Regarding the *objective measures*, we can report the following results: The seven design thinking teams generated a total *quantity* of between 21 and 44 prototypes, with an average of 34 prototypes per team. The most prototypes have been generated in the first phase, followed by the second phase, as indented in the design thinking cycle. The teams that had both the best objective and subjective performance and process measures also developed an above average number of prototypes. Surprisingly, the team with the business model innovation task developed the most prototypes of the three selected teams with 34 prototypes in total, followed by the product innovation team with 39 prototypes and last, the service innovation team with a total of 21 prototypes. Based on idea generation research (Diehl & Stroebe, 1987; Simonton, 1999), we have expected that the product innovation team would generated the most ideas, followed by the service innovation team and then the business model innovation team.

Hence, in our study on design thinking innovation teams, we can show that the amount of developed prototypes, which is often considered the critical factor for the selection of the best idea (Diehl & Stroebe, 1987; Simonton, 1999), seems to be indeed an indicator for the quality of the best idea. However, as the service innovation team developed the least amount of prototypes, but still a great idea in the end, this finding has to be examined carefully and should be verified by future research.

Furthermore, based on the objective expert rating to measure the *quality* of the developed prototypes, we can show that all design thinking teams managed to select the best idea they developed in the course of the 10 months. However, differences appear for the item of the implementation opportunities of the prototypes. Prototypes which are rated especially high regarding their novelty and creativity appear to be rather difficult to be implemented in a timely manner, as rated in the expert rating in the case of team Venus, the product innovation team.

Regarding the *subjective measures*, we can report the following results: The teamwork quality scale (TMQ) is positive related to team performance in the innovation literature (M. Hoegl & Gemuenden, 2001). While the business model innovation team and the product innovation team both ranked their team work quality as expected with a highly motivated and productive beginning, they reported very low motivation and productivity in the dark horse phase. However, the teamwork improved considerably afterwards until at the end of the project, when the teamwork quality has been rated about as positive as at the beginning of both teams. The service innovation team, however, which was the only team working in a virtual team; reported strong ups and downs, compared to the other teams. Comparing the team work quality ratings and the objective performance ratings, we find that the teams collaborating constantly well over time have better final quality ratings as compared to the team which experienced difficulties. However, as the majority of the seven teams experienced similar difficulties, as intended, in the dark horse phase and only one of the design thinking teams, working in a virtual team experienced continuing difficulties, we suggest that this is based on the virtual collaboration and requires further examination in future studies.

Team reflexivity has also been found to be positively related to team effectiveness (Martin Hoegl & Parboteeah, 2006). Again, we have found that team reflexivity was lowest for the service innovation team working in a virtual team, with major ups and downs. Interesting as well is that the reflexivity level of the beginning of the design thinking innovation project is reached again in the functional prototype phase, but not with the final prototype, as in all other teams.

The team climate inventory (TCI) subscales of vision and team participation by Anderson and West (1998) surprised for the service innovation team again, as the team started with a rather pessimistic vision, which improved and remained constant for the dark horse and functional prototype phase, while again lowering for the final prototype. Similar curves are observed for the participation scale. All other teams started with high ratings and reported strong decreases of vision and participation safety in the dark horse phase which went up for the functional prototype phase and continued to reach the level of the first phase with the final prototype.

The overall innovation team performance of Blindenbach-Driessen and colleagues (2010) continued to support the findings of the above described scales: While the business model and product innovation team reported insecurities regarding the quality of their performance and the likelihood of success especially in the dark horse prototype phase, the service innovation team started not very optimistic, but reported confidence in the dark horse phase and ended with below average performance ratings.

Overall, the following findings could be verified: Industry experts confirmed that the best ideas were selected in all design thinking teams as final prototypes out of all prototypes generated. The subjective measures from the teams confirm that the teams were satisfied as well with selection as the quality of ideas developed at the end. We have found that the service innovation team working in virtual collaboration mode had difficulties for the majority of the project. Additionally, this team had generated the smallest amount of prototypes and experienced low satisfaction with process, team communication, and team work quality in the divergent phase compared to the other teams. Surprisingly, the final prototype was assessed and determined as in the top quartile of all the final prototypes delivered. Both the team with the product innovation task and the business model innovation team have been among the most stable teams, nevertheless the product innovation team was not assessed as one of the best teams of the year.

6 Contribution: What does the submission add to current understanding?

Design thinking is a human-oriented innovation method, which has originally been used for innovation in mechanical engineering and is now applied to a much wider field, especially business administration environment. So far, there has been no test of the effects of design thinking in this environment. We have applied team innovation process and outcome scales to compare how design thinking teams are affected by different innovation tasks.

The study provides a preliminary overview on design thinking teams working on different innovation tasks and reports effects of the innovation task on both outcome and process. We have analyzed how design thinking teams work when they are not, as previously often the case, composed of mostly mechanical engineers (Skogstad, 2009; Dym et al. 2005) but business students, for which generating prototypes is an unusual activity..

In our preliminary study we report that the three innovation types have been mastered, with the final prototypes from all teams receiving high independent quality ratings. Also, the innovation type did not impact the total number of ideas, or prototypes, generated by the teams.

Specifically, we have found that the subjectively measured output ratings support very much the objectively measured output ratings, with the only exception being the service innovation team, which collaborated as virtual team. The difficulties the team reported impacted the subjective ratings to a great extent. However, although the team was not overly satisfied with its performance, the industry partners of the team expressed great satisfaction in their quality ratings. Virtual teams are of much research interest (Linda & Charles, 2007), which most focus on how collaboration and communication can be facilitated. In practice, virtual teams are a reality in the globalized economy for many firms. In our research, we observed that the virtual collaborating team experienced significant difficulties in the innovation process. However, the impacts on the final prototypes have been marginal. Thus, we would recommend that future research could focus on comparing virtual and traditional design thinking teams working on a comparable task, for example, working all on service innovation tasks.

Girotra and colleagues (2010) have argued that the most important step in idea generation is the selection of the best generated idea, not just the generation of many ideas. Contrary to our initial expectation, it was not the product innovation team that generated the most ideas. Instead, the business model innovation team with the most complex and abstract innovation task developed more prototypes than the product innovation task team. As our sample is small, we may not generalize from our findings and recommend instead further research endeavours do enlarge the sample.

Future research may also focus on the impact of coaching in the process, especially in the dark horse prototyping phase, which caused the most difficulties for almost all teams across all measures. Another interesting research focus could be in the shift from diverging to converging thinking. In design thinking teams, the conversion of the insights and learning's takes place in the converging phases towards the creation of the final prototype.

7 Practical implications: Who will gain why and in which way from the findings?

The findings of this study are especially relevant for practitioners thinking about changing or adapting current innovation processes. First of all, we report first evidence that design thinking can be applied for more complex and abstract innovation types such as service and business model innovation, although it has so far mostly been used for product innovation.

Design thinking has received much attention and we could show in our preliminary study that generating many prototypes by following the design thinking milestones, which facilitate the generation many as well as of rather distinct prototypes, leads to the generation and selection of the best prototype and therewith idea. This is an important finding according to Girotra and colleagues (2010), as the selection of the best idea is a

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crucial step for firms. Even the teams which have experienced major difficulties in the process, as the virtual service innovation team, have developed a good quality final prototype which has been valued by the industry partner.

Further, the creation of many prototypes does supports the selection of the best ideas, however, even when the total number of prototypes falls below the average of number of prototypes for the service innovation team, the final prototype has been rated just as good. Design thinking fosters the creation of many and distinct prototypes in the different prototype phases, which provides an opportunity for teams to improve the overall performance through continuous testing and learning and therewith enhances the chances of selecting the best idea in the end.

Finally, as an anecdotal note on how to gain ownership on outsourced idea generation: The early and constant involvement and at the same time relative distance to the industry partners who sponsored the design thinking project facilitated the innovation process, as the input helped to guide the team, as well as it facilitated the transition of the idea and implementation in the firm, with the industry partner gained continuously ownership of the idea.

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