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PLAYFUL CONCEPTUAL DESIGN OF INDUSTRIAL PRODUCT-SERVICE SYSTEMS: AN EXPERIMENT

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ABSTRACT

It is known well that the development of industrial product-service systems (IPS2) is a challenging task for solution providers. In order to enable the full potential of these new systems the companies have to establish a new mindset among their developers. This is necessary to overcome the barrier of thinking in separate product and service domains. This leads to the fact that new ways of teaching the aforementioned cross domain thinking need to be broadened. This paper describes an experiment which aims at the evaluation of such an approach. Based on principles of business games it supports the development of initial concepts of an IPS2. In the experiment 122 students were asked to create a concept of an IPS2 solution by using either this gamestorming or a traditional brainstorming method. The research hypothesis states that the game-based approach supports a better exploration of the underlying solution space and so the adoption of the new IPS2 mindset is more effective. Results have shown that this hypothesis has been approved to be right. Further work will ask more precisely after certain details of this process in industrial environments.

Keywords: creativity, conceptual design, design methods

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1 INTRODUCTION

Providers of manufacturing solutions are required to establish long-term customer retentions with their solutions in order to face problems of globalization and customer markets. The development and provision of industrial product-service systems, shortened to IPS^2, which realize this customer-oriented individualization is a consequence of this demand. The need to establish this new way of thinking is well known and has been proven in various studies (Meier et al., 2010). But it poses to be a challenge to broaden the so-called “IPS^2-mindset” in the providers’ development departments (McAloone, 2011).

Since the bundling of product and service components to an integrated system requires an intensive interplay of several organizational parts of a company the conventional development process has to be adapted. Traditional process-models of product- or service domains do neither consider cross domain thinking nor support cross hierarchical decision making. Especially in early stages of a development project these barriers in the stakeholders’ mind hinder really creative and innovative solutions. In order to enable the creation of domain comprehensive solution architectures new creativity methods for supporting conceptual design need to be established (Roy et al., 2012). This helps towards ‘barrier-free’ thinking and harmonization of product- and service engineering mindsets.

One such ‘barrier-free’ creativity method is provided by Meuris et al. (2013). Since evidence suggests that games in the context of creativity produce more and better results, this approach is based on basic principles of business games as they are proposed by Gray et al. (2010). Within this game two or more players describe requirements, solution elements and potential failures of an IPS^2. By the ability to react on failures with new ideas the participants can score. So, each of them has primary the goal to increase personal score. But by doing so the solution space of the specific problem is explored and a deep solution understanding is broadened. After first impressions on the usability of this way of idea generation in various workshops, it could be questioned if a game-based creativity method leads to more or ‘qualitative better’ results than common creativity methods like brainstorming.

This paper presents the results of an experiment which aims at the aforementioned research question. A group of students were asked to generate a concept for a new product-service system either in a brain- or a game-storming session. The solutions are compared to each other and this allows conclusions on the effectiveness of each method. The game-storming approach and the conducted experiment are explained in section 2. The results of this experiment are presented in section 3, followed by the discussion of the results in section 4.

2 METHODS

2.1 IPS^2 conceptual game storming

According to Meier et al. (2010) the core of the new understanding of IPS^2 can be seen in the change from selling physical objects or industrial services to a performance based sale of a functionality. Therefore an IPS^2 is not only a simple problem solution. Moreover it aims at adding value to the customers’ production process with respect to increasing both, customers’ and suppliers’ benefits. This transition from providing a technical solution to the development of a value is grounded in the conceptual design stage of a development process because this stage’s goal is the generation of a solution architecture which shows potential realizations of the customer needs and how value is added. Thus, it has to describe the structure and the interrelationships of its artifacts.

A model based approach to allow the description of this interplay is provided by Sadek and Koester (2010). This model defines IPS^2-artifacts which dissolve the aforementioned barrier of product and service domains.

The so called heterogeneous IPS^2 modeling approach aims at the determination of a structure of performance artifacts that add a certain customer value. IPS^2 artifacts originate from the “function” term. Pahl et al. (2007) define such a function as a combination of a noun and a verb. In this context the noun represents a structure of tangible objects within the IPS^2 which possess a certain state. Verbs are a placeholder for processes (Operands) which enable the change of an object’s state. Consequently a conceptual model of an IPS^2 is generated by successive adding elements to the functional-, the object- and the process-layer. Furthermore, relationships between elements of different layers can be described. Finally, a variation in the level of abstraction to describe elements on each single layer can be done. For this reason the approach is called heterogeneous modeling approach.

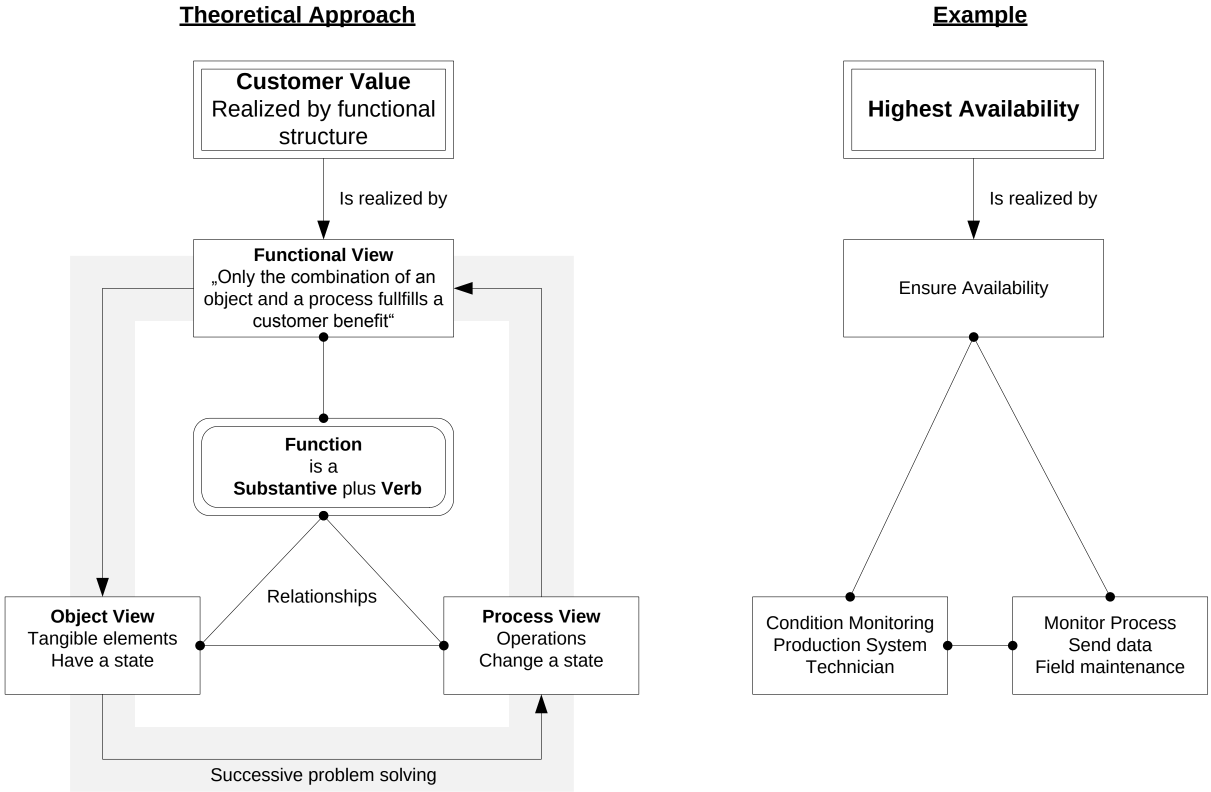

Figure 1. The heterogeneous modeling approach by Sadek (Sadek and Koester, 2010)

Figure 1 exhibits the main statements of the heterogeneous modeling approach and shows an easy example of its application. It has been proved to be a reliable model to describe IPS^2 in early stages of a development process. Since communicating the idea of IPS^2 was not a primary goal of this approach, the industrial application turned out to be inefficient. In order to address this issue of undeveloped IPS^2 mindset a teaching approach is provided by Meuris et. al. (2013). It combines both, the basics of heterogeneous modeling and principles of business games. With respect to the fact that an IPS^2 is always a customer individual problem solution the original game is divided into three different sessions. In a first session the participants learn the new paradigms and dimensions of an IPS^2. Since this goal requires high cognitive effort it is suggested to analyze analogies of everyday's life where product and service harmonize. The second session aims at transferring this new knowledge to the individual problem. In the understanding of the heterogeneous model this transfer is basically the search for main artifacts (functions) and boundary conditions of the new solution. Once these functions are found new solution elements (objects and processes) are created in the third session. Because of reasons of time, the conducted experiment only focused the third part of this chronology. Therefore the following remarks apply to the solution generation process.

The game-storming approach consists of four main elements: moderator, at least two participants, the board and specific accessories like playcards, post-its, etc.. The moderator guides the participants through the whole process. He is aware of the rules. Furthermore he also has a deep understanding of the above mentioned heterogeneous modeling approach. Like the moderation in traditional brainstorming sessions the moderator is not allowed to comment or add any idea. An important task of the moderator is to supervise the level of abstraction during the creation of solution elements because the participants might get lost in details. The participants have to create solution elements on the object- or process-layer and can earn scores for each solution element which they created in a fixed time period. The amount of scores depends on the originality of their ideas. A solution element which was created by both participants is only half the score than an exclusive idea. This principle originates from the traditional game 'categories'. The participants can also score if they find potential failures in the opponent's solution elements. By this mechanism obvious or impossible solution elements can be avoided. More over this is a key factor to the participants' motivation. Figure 2 depicts the different actions of the participants during the developed game.

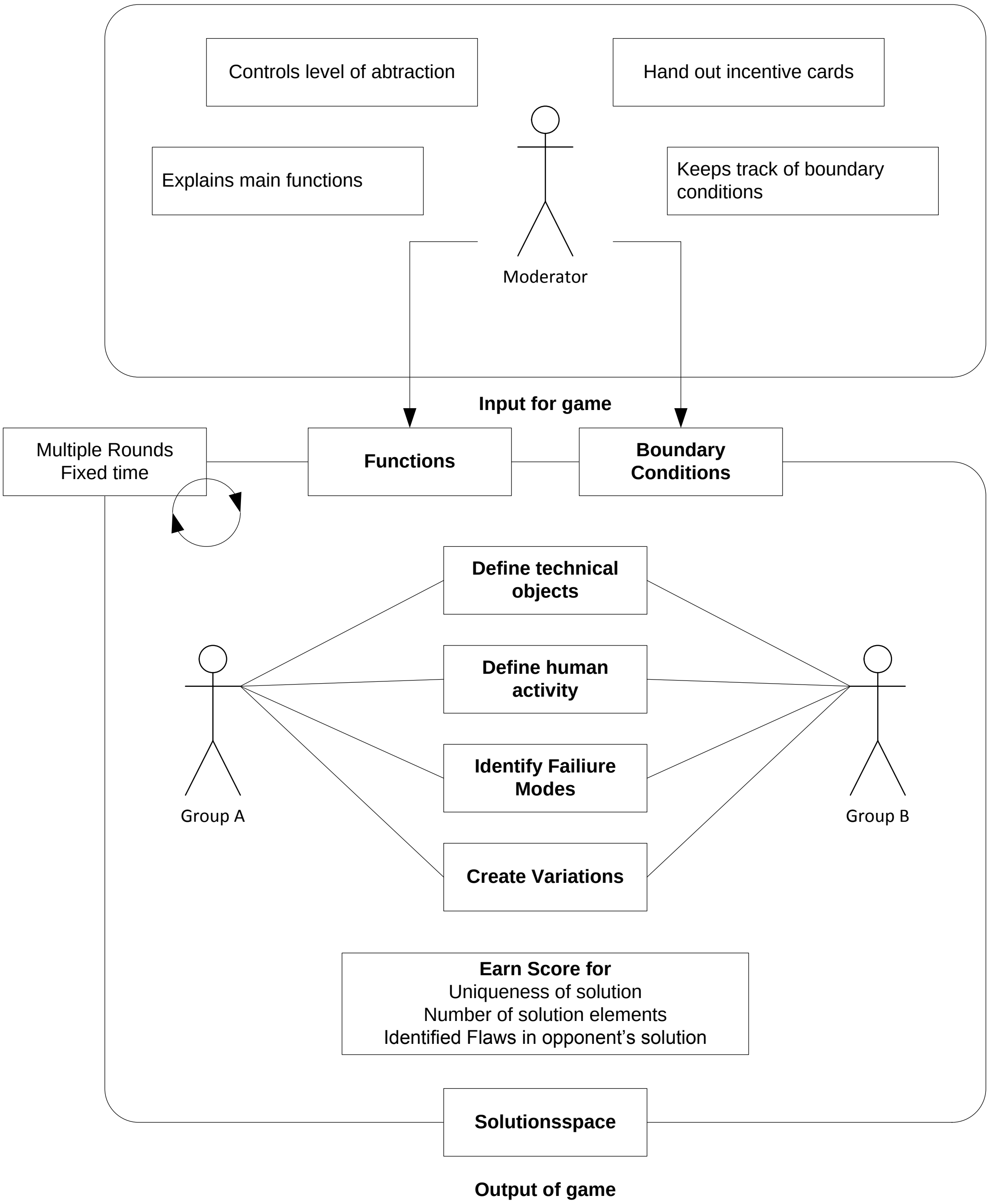

Figure 2. Actions during IPS² conceptual design gamestorming

For each given IPS² artifact there are two possible categories (technical object or a human activity), which can contain solution principles. Either the function is fulfilled by a technical object or a human activity. Consequently, this game is about the "battle" of "technical objects" versus "human activities". For instance a car can be washed (function) by an automatic washer system (technical object) or specialized personnel cleaning the car (human activity). At the beginning of the game the participants have to find as much solution principles as possible for a single function. After that it is requested to find flaws related to the solutions found before. Thereby the participants create barriers against the identified technical objects or human activities to hinder their chances of success. This is the aforementioned mechanism of assorting weak solutions. Further support for this cross domain thinking is given by so called incentive cards (e.g. "force the participants to find solutions by changing their viewpoint" or "to reframe the function into another field of knowledge"). As a result of this round, solution principles and alternatives have been identified for each predefined function. Finally, the participants have to decide about the different solutions and now are able to arrange these elements into a systematic order.

2.2 Hypothesis

Since the idea of battling against each other seems to be very motivating for each participant it could be questioned if such an approach leads to different (qualitative / quantitative) results than the application of traditional creativity methods. The aim of this paper is to present an experiment to give possible answers to this question. In the following remarks the main research hypothesis for the experiment is presented.

According to principles of systems theory it is necessary to generate a large amount of different solutions in early development stages. It can be shown that the more principle solutions are generated the merrier is the final concept of a product (Yang, 2009). The amount of different solutions is a measure for the size of the solution space explored during conceptual design.

That leads to the hypothesis:

The solution space which is explored during a conceptual design creativity session is significant higher when using a gamestorming method!

This hypothesis enables the underlying research question:

Which creativity method (traditional brainstorming or new game storming) has a higher output of different solution elements?

2.3 Subjects

In order to get a large amount of experimental data 122 students attending the product development course held by the university of Bochum, faculty of mechanical engineering, were asked to participate in an experiment. All students have a bachelor degree in mechanical engineering which allows the assumption that all participants feature the same technical knowledge and methodological skills. Furthermore all students have no experience with IPS^2, since the topic is handled in later lectures. Individual skills like creativity which might have an influence on the results were assessed during the experiment.

2.4 Experiment procedure

The procedure of the conducted experiment is displayed in figure 3. To minimize influences of personal relationships the basic set of 122 students was randomly divided into groups by four students (Step 0).

Step 1 – Creativity Test

In order to handle the aforementioned influence of individual creativity all group members had to participate in a common creativity test. This test consists of three parts where different aspects of creativity are focused. These aspects suppose to be related to general challenges in IPS^2 conceptual design as mentioned in Meuris et al. (2013). In the first part a participant has to create up to 30 sketches which base on a simple circle. This activity addresses the ability to think about high order issues and connections between them. In case of an IPS^2 it is a measure for the participants' systemic and holistic viewpoint. The second part is known as alternative use test. Within this test an alternative use for a given object (e.g. a paper clip) has to be found. The total amount and variety of the found uses is a measure for participants' ability of considering different solutions for a single problem. Part three focuses on completing an incomplete figure. The participants had to complete a geometrical figure under certain constraints. This test examines the ability to overcome predefined patterns.

Step 1 was conducted to subdivide one group by four into two groups by two: the more and the less creative. Each pair had to take part in either a brain- or a game-storming session. The assignment of groups (creative or less creative) to methods (brain- or game-storming) swapped after half the basic set. This was necessary to handle the influence of creativity.

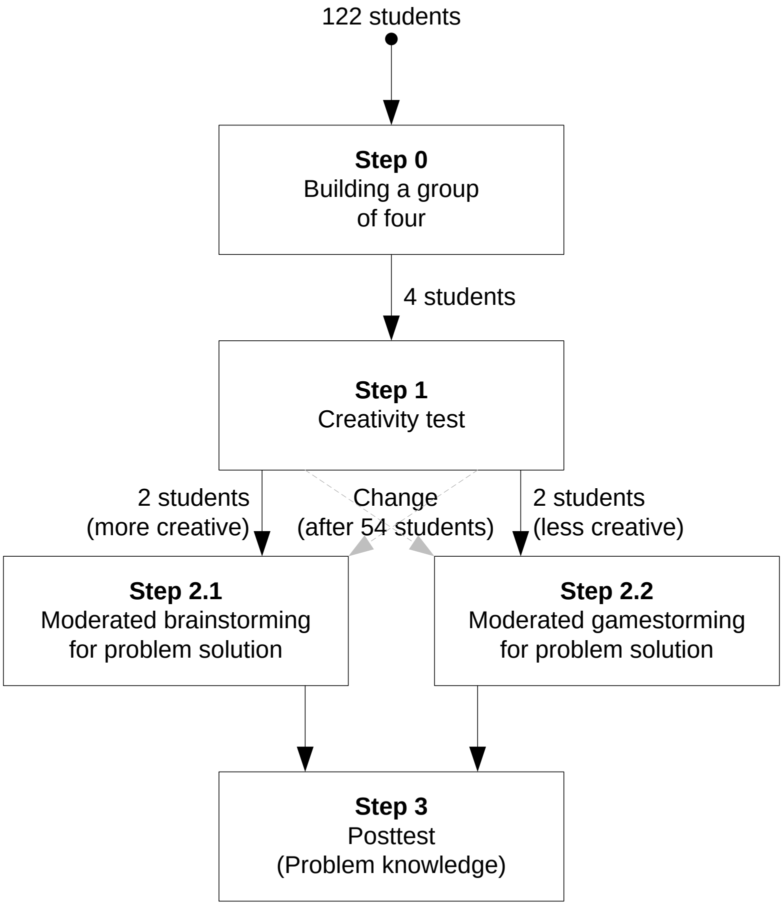

Figure 3. Procedure of experiment

Step 2.x - The creativity sessions

In step 2 the brain- or game-storming session was arranged. Two persons were guided by a well trained moderator who explained the rules and controlled the process. In a fixed time period of 30 minutes the students had to find solution elements for a given IPS[2] problem. They had to create an e-mobility solution on the campus of the Ruhr-University Bochum which should base on segways (the technical core). Though the students should assume the role of development engineers the experiment's problem addressed their everyday life. So, no further explanations were necessary.
Furthermore, the problem was designed with boundary conditions which all students should understand by their experiences on the campus.

For both sessions main functions were predefined:

- Deploy segways on campus.
- Guide segway users through campus.
- Admit users to segway.
- Authorize users.
- Overcome barriers (e.g. stairs) on campus.
- Return segway.
- Protect user from weather (rain, snow).
- Load segway with electrical energy.
- Protect segway from unauthorized access (e.g. theft).

All these functions allow a solution either with technical elements (objects) or with human activities (processes). Furthermore the students had to think about possible failures in their solutions. That leads to the fact that there is a large solution space for this problem and many different variants of a final concept are possible. With respect of the research hypothesis the question is which group (brain- or game-storming) created more different solutions. Exemplary results of the creativity sessions which are the basis for the evaluation are displayed in Figure 4.

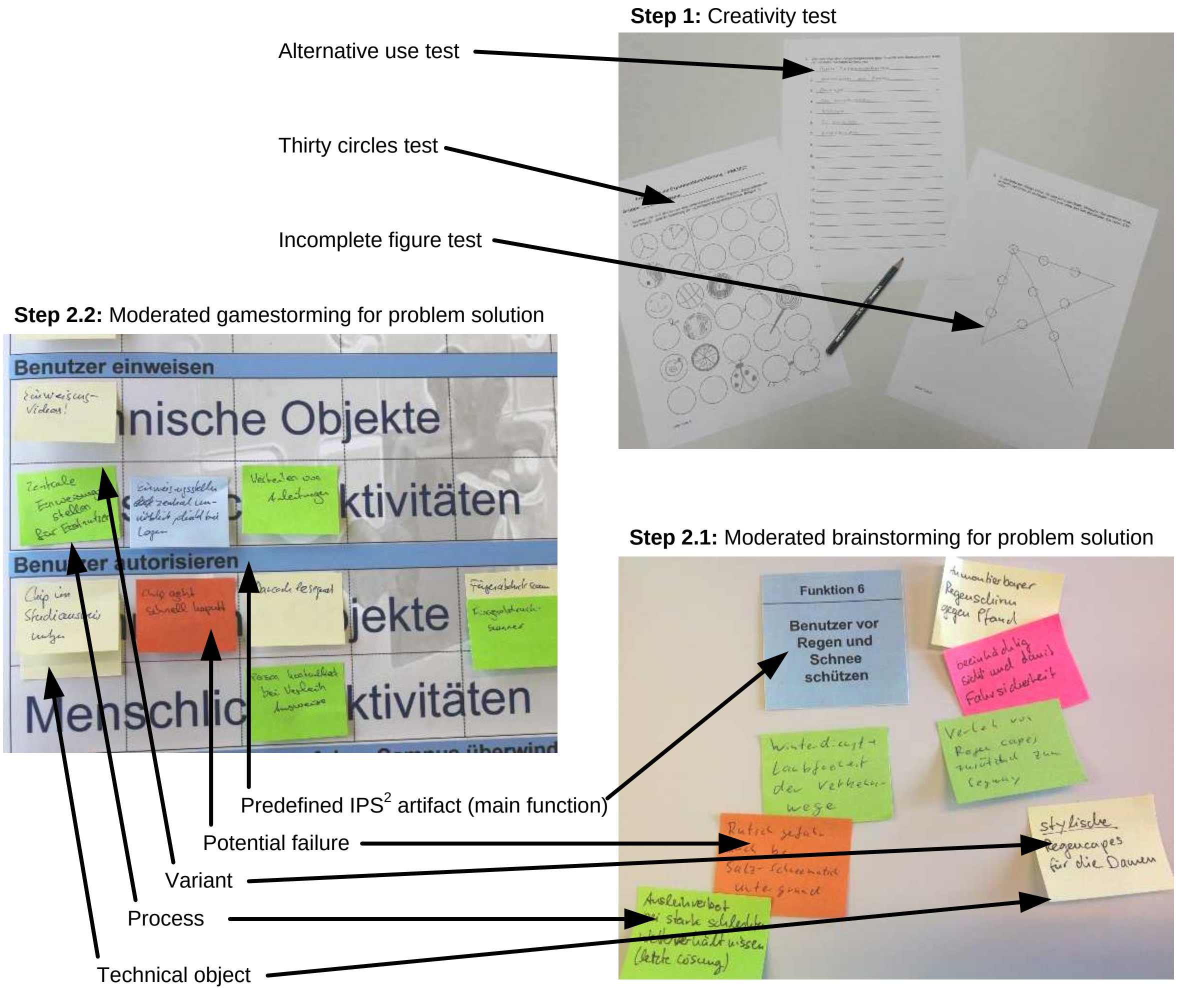

Figure 4. Exemplary results

Step 2.1 - Brainstorming session

The brainstorming session (see Figure 4-bottom) can be seen as an adaption of the gamestorming. But it was not conducted as round based session and the possibility of earning scores was removed. The predefined main functions were printed on post-its and the students had to attach their own solutions, either objects or processes, to them. Furthermore it was possible to add failures to certain elements. The role of the moderator was to guide the participants not to get lost in details.

Step 2.2 - Gamestorming session

The gamestorming session (see Figure 4-left) was conducted as explained in Section 2.1. Two participants battle against each other to earn scores. In different rounds they had to create solution elements, failures and variants to existing solutions. The moderator was urged not to give hints on content. He only was allowed to guide through the gaming process and also avoid a too detailed description of the solution.

Step 3 - Posttest

The final is a questionnaire which asks for detailed problems which occur in the general e-mobility concept on the campus. This step aims at the participants' problem perception. Answering these questions is only possible when having a deep knowledge of the problem.

3 RESULTS

In the following section the results of the conducted experiment are presented. First, one has to clarify if there is any influence of the students' individual creativity skills. After that the explored solution space will be analyzed.
The first analysis deals with the influence of individual creativity in the creativity sessions. Since this skill was assessed by common accepted test (see Section 2.4) it is worth knowing how the amount of generated solutions differs in both groups of creative and less creative students. The diagram in Figure 5 exhibits how many points were reached by how many groups. The median is at 10.5 points. That means that by a total sum of 60 groups 30 groups reached more than 10.5 and 30 groups reached less than 10.5 points. The first results is that a division in more and less creative groups is well possible because most participants can be found clearly far away from 10.5 points (regard the two peaks).

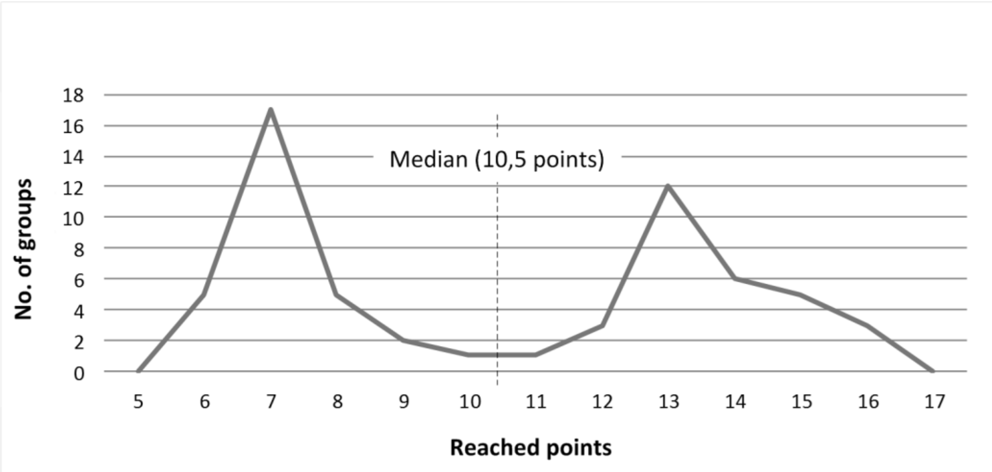

Figure 5. Distribution of reached points in the creativity test

Table 1 contains the number of found solution elements in the brain- and gamestorming session with regard to creative and less creative participants. The data in this table is already adjusted. That means that solution elements which obviously have no connection to a main function or which are not logical are removed. The following results can be stated:

– The practical realization of creativity tests during creativity session is well applicable.
– If found solutions are adjusted regarding their functionality or their logic no relevant differences between creative and less creative students can be found. This applies to the game- and the brainstorming session.

Table 1. Comparison of found elements of creative and less creative students

	Brainstorming		Gamestorming	
	No.	**Std. deviation**	**No.**	**Std. deviation**
More creative	32,0	5,8	42,8	10,2
Less creative	32,8	6,7	43,5	4,7
Entirety	32,45	6,3	43,18	7,7

3.2 Found solution elements

The discussion of the hypotheses (Section 2.2) requires counting the found solution elements in both sessions. According to results of influence of creativity it is not necessary to distinguish between creative and less creative students. Table 2 shows the results of this analysis.

Table 2. Comparison of found elements in brain- and gamestorming sessions

	Brainstorming		**Gamestorming**		**Delta** $\left(\frac{GS}{BS} \text{ x } 100\%\right)$
Entirety	144		217		+ 50,69%
Average per group	32,45	σ = 6,3	43,18	σ = 7,7	+30,07%

The entirety of all gamestorming participants found 217 different solution elements. The brainstorming participants created 144 different solution elements. Another key differentiator is exhibited in table 3. It shows the number of exclusive elements. These elements were found exclusively by one group (brain- or gamestorming). Half of the solution elements which were found by the gamestorming group were not identified by the brainstorming group.

Table 3. Comparison of exclusive elements found in either brain- or gamestorming sessions

	Brainstorming
Total no.	144
Exclusice elements (not found by gamestorming)	53
Percentage	36,81%

	Gamestorming
Total no.	217
Exclusice elements (not found by brainstorming)	126
Percentage	58,06%

4 DISCUSSING THE RESULTS

In order to evaluate a new conceptual IPS^2 design approach which is based on principles of games, an experiment was conducted. The experiment's hypothesis questioned the difference between the explored solution space of this approach and common creativity methods like brainstorming. The amount of different solutions found during a creativity session was identified as a measure for the size of the solution space.

It can be argued that gamestorming seems to be a reliable method to generate a large amount of solutions during early stages of an IPS^2 development project. Setting the traditional brainstorming method as reference it can be seen that there are about 50% more results generated in a gamestorming session if all groups are considered. This result is similar when regarding an average group. The percentage share is about 30%. Consequently, the evaluation of the experiment has shown that the test persons which developed a solution by a game-based conceptual design approach created a bigger variety of different solution elements than brainstorming teams. In section 2 the gamestorming approach was introduced as teaching approach for the IPS^2 mindset. The results of the experiment have shown that the participants who had no previous knowledge about product-service systems were able to create an initial concept of a system. They already have considered different variants and potential flaws of their solutions. This indicates increased skills towards an IPS^2 conceptual design. Consequently, the gamestorming approach seems to be a reliable way of teaching the new mindset on the fly (learning by doing).

An additional advantage of Gamestorming is the moderator's ability to take direct influence on the idea generation by varying and modifying game rounds according to the situation. In a typical case, the IPS^2-developers focus on generating technical solutions because they are more familiar with it. In order to get the best IPS^2-concept, it is necessary to consider both, technical and human dominated solutions. For this case, the moderator can vary the different game rounds or modify the rounds, to get a more balanced allocation of products and services. For example, he adds a "service-round". In such a round the IPS^2-developers have to focus on generating solution principles which are realized by human activities and just get points for each new one. Another possibility is to set bonus points for each identified human activity, so that the gamestorming participants have an incentive to look for human dominated solutions.

Another qualitative feature of the developed IPS^2 is that potential flaws are identified as early as possible. To support the identification, the game orientated approach includes specific rounds, where the users concentrate on searching problems of the IPS^2 and its solutions. With that support, more than half of the elements identified by gamestorming are weak spots. These spots have to be considered in subsequent development phases to reduce weak spots of the IPS^2 within the IPS^2 operation phase to a minimum.

The results have shown that, even if a development team is very experienced in applying creativity methods, the gamestorming approach can encourage new impulses and thinking patterns to a team.

Furthermore, the aspect of battling against team members motivates the participants. Also learning the IPS² mindset on the fly is one important argument to apply this approach to new problems.

5 FURTHER WORK

As gamestorming in the context of multidisciplinary design problems could be proved as an effective way to create solutions more research in this field has to be done. Especially the possibility to earn personal score during creativity sessions seems to have a very positive effect on the outcome. There should be done more research in combining traditional methods with these mechanisms.

The amount of data generated by the experiment allows further analysis. One point could be to investigate the effectiveness of learning the IPS^2 mindset by this approach. The utilization of the posttest questionnaires enables this further study.

One boundary condition of the conducted experiment was the assumption that all participants have equal technical and methodological knowledge. However, the application of game-based creativity methods in real industrial environments needs to consider the highly distributed knowledge among certain stakeholders. Thus, further experiments should focus on mechanisms of knowledge transfer in multidisciplinary development projects.

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