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Is engineering creativity different from creativity in other disciplines?

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IS ENGINEERING CREATIVITY DIFFERENT FROM CREATIVITY IN OTHER DISCIPLINES?

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ABSTRACT
Creativity is an important prerequisite of innovative products developed in companies (Amabile, 1996). If we want to improve the innovative capability of a company one starting point is to improve the creativity of individuals involved in product development, e.g. the creativity of product development engineers. The creativity of product development engineers contributing to technical products can be increased by selecting the most creative engineers for employment, promoting the creative ones and by offering creativity trainings. Some research is raising the question if creativity in different domains is different or the same (Feist, 2005; Kaufmann and Baer, 2004). To understand the particularities of engineering creativity it is critical to develop appropriate assessment tools and creativity trainings. This paper presents a preliminary study indicating domain-specificity of creativity in product development engineering. Self-reported perceived criteria of creativity and creative behaviour of 22 engineers in product development were compared with self-reported perceived criteria of creativity and creative behaviour of 7 artists using a qualitative content analysis. Conclusions for selection, training and additional managerial issues are drawn.

INTRODUCTION
The more the global market is pushing for cost effectiveness the more strategies beyond competing with cheap production structures are important for western industrial companies (Goffin and Mitchel, 2005). The capability to develop new products and bring them successfully onto the market is generally accepted as a source of competitive advantage for companies. In this paper we will focus on the individual perspective in product innovation in business organisations. Creativity is an important ingredient of innovative products developed in companies – or as Amabile states: “…creativity by individuals and teams is a starting point for innovation” (Amabile, 1996, p. 1154). The concept of creativity can be interpreted in many different ways. Taylor (1988) cites more than sixty different definitions. A definition which is shared on a meta-level by many researchers could be phrased as follows: creativity means to find novel and adaptive solutions to problems (see Amabile, 1996; Feist, 1993; Simonton, 1988; Sternberg; 1988). “The adaptive criterion is necessary to distinguish truly creative thinking from merely different and/or pathological thinking” (Feist, 2005, p. 274).
If we want to improve the innovative capability of a company one could begin improving the creativity of employees involved in product development, e.g. product development engineers. There are two general approaches to increase the creativity besides enhancing organisational framework conditions (e.g. organisational culture, working conditions). First, a company can select the most creative engineers in the hiring process and in promotion decisions. Second, a company can enhance individual creativity through training.

Regarding the selection process for hiring or promoting employees, there are various creativity assessments (Puccio and Murdock, 1999; Malakate, Andriopoulos et al., 2007) available. It is impossible to present all available assessment methods and tools in detail (already Kaltsounis found more than 250 instruments—Kaltsounis, 1971; 1972). Puccio and Murdock (2007) cite more than 300 tests, inventories, rating scales and checklists that claim to measure some aspect of creativity or its correlates. An overview on recent methodologies has been published by Puccio and Murdock (1999). A variety of tools can be used: questionnaires, checklists, rating scales and interviews (Malhotra, 1993). One can distinguish two principal research approaches in the area of assessing individual creativity. The so-called level approach (Isaksen and Dorval, 1993; Isaksen and Puccio, 1988) investigates the question how much creativity one individual possesses. More recent research has focused on various styles of creativity (Kirt, 1976; Isaksen and Dorval, 1993). This so-called style approach describes how people differ in the way they show their creativity. This approach promotes the concept of more than one way to be creative. Until now there are no creativity assessment tools available tailored to special domains like product engineering.

That creativity can be enhanced through training is widely accepted (Amabile, 1983; Amabile & Tighe, 1993; Cropley, 1992; Finke, Ward and Smith, 1992; Sternberg and Lubart, 1996; Hunsaker, 2005; Ma, 2006; Scott, Leritz et al. 2004). Some significant effects for children and adolescents could be found (e.g. Covington, Crutchfield, Davies & Olten, 1974; de Bono, 1973; Adams, 1986). Effective training courses for adults are carried out and positive training effects can be found (see for an overview Ma, 2006; Scott, Leritz & Mumford, 2004; Rose & Lin, 1984). Although the trainings are carried out in different professional domains the domain specificity of creativity has not been explicitly taken into account.

To understand the particularities of engineering creativity in product development it is critical to develop appropriate assessment tools and creativity trainings. The goal of this paper is to answer the question of domain-specificity for the field of product development engineering respectively what behaviour is important for creativity in this field.

**DOMAIN-SPECIFICITY**

A scientific debate is going on in recent research if a general factor c (analogous to g in intelligence research) can be defined or if creativity is domain-specific (Baer, 1994a, 1994b; Crammond, 1994; Plucker and Runco, 1998). The term “domain” is somewhat fuzzy. The evidence for domain-specificity of creativity includes both definitions, specificity in the sense of broadly defined cognitive domains (e.g. science, mathematics, arts, etc.) and more narrowly defined task respectively content domains (e.g. poetry-writing, collage-making). “Micro-domains” (Karmiloff-Smith, 1992) or “task specificity” (Baer, 1993) are more appropriate terms than domain specificity for the second class just
described above (see Kaufmann and Baer, 2004). In this paper we will focus on the more broadly defined domain-specificity.

Plucker (1998) stated that the differences between research supporting domain specificity and research postulating generality might be caused by a method effect. Performance assessment studies and personality trait studies tend to find evidence for domain specificity (Baer, 1996; Runco, 1989) while creativity checklists and traditional assessments or tests are more likely to find evidence of generality (Hocevar, 1976; Plucker, 1999). Runco (1987) exemplified this effect by using both self-report and performance-based assessments of creativity. The self-report scales, which focused on the quantity of creative activities in various domains showed generality. The performance assessments focusing on the quality of creative activities in different domains pointed to domain specificity of creativity.

But even those who argue for the existence of generality in creativity recognize that people’s creativity varies across domains (e.g. Amabile, 1996; Conti, Coon and Amabile, 1996; Plucker, 1998). Amabile (1996) offers with her componential theory an inclusive sight. There are general all-purpose creativity thinking skills and traits and there are domain-specific skills and traits (additionally there is a third component, task motivation, to determine the actual level of creative performance one demonstrates on a given task). Therefore it is not sufficient to talk about general results regarding creativity if one wants to foster creativity in certain domains.

Feist (2005) summarizes profoundly the extensive research on personality traits found with creative people. He distinguishes two creative domains, science and arts, and states distinct differences in personality traits for both domains. Artists are more affective, emotionally unstable, as well as less socialized and accepting of group norms whereas scientists are more conscientious. But there are also shared personality traits for the creative in these two domains. They tend to be open to new experiences, less conventional and less conscientiousness, more self-confident, self-accepting, driven, ambitious, dominant, hostile and impulsive.

Kaufmann and Baer (2004) found further evidence for certain domain specificity. They asked 241 participants to rate their own creativity, general and in the following domains: science, managing interpersonal relationships, writing, art, interpersonal communication, solving one’s own personal problems, mathematics, crafts and bodily/physical movement. The results showed that three factors could be found doing a factor analysis of the domain ratings: empathy/communication factor, “hands on” factor (including e.g. art, crafts) and mathematics/science factor.

It is interesting that the third factor (mathematics/science) does not correlate with general creativity ratings. This shows one more time that creativity is not purely a monolithic construct. It seems that creativity in mathematics/science is not regarded similar (at least in self-reports) to creativity in general.

In this paper we want to answer the question what specifies creativity in the field of product development engineering. Feist (2005) and Kaufmann and Baer (2004) are showing that there are differences between the domain of mathematics/science and other domains, e.g. artistic occupations. Unfortunately most of the studies are done with scientists (working in universities or research institutions) or students. Product development engineers might quite differ in their creativity from this group of subjects. Differing environmental factors due to different organisational structures, various tasks
and job descriptions and different need to work with an application focus are only three possible differences between scientists and product development engineers. This could also lead to different criteria in the definition of creativity. A better understanding of the qualitative descriptions of creativity by product development engineers can help to develop tailored and more effective trainings. It also can help to develop more suitable selection criteria for product development engineers.

STUDY
This study is a first step to investigate the domain-specificities of creativity in product development engineering. To answer the qualitative question how creativity is described in product development engineering and what characteristics define creativity a qualitative content analysis of self-reported characteristics and behaviour was chosen. As a comparison group we used artists. In one aspect product development engineers have a similar job to artists: an important part of the job is to create something new. But a lot of other conditions as involvement in an organization or compensation rules are extremely different. If we cannot show differences between artists and engineers their maybe no differences between engineering creativity and creativity in domains.

Participants
There were N=29 subjects participating (22 product development engineers and 7 artists) at this study. Product development engineers were defined as engineers working in R&D departments, engineers employed for innovation departments of manufacturing companies or engineers of specialized engineering companies in the field of open innovation. The comparison group consisted of graphic designers, designers and artists. To keep the response rate high participants personally known to the authors were asked to take part in this study. 53 product development engineers and 45 artists were requested by e-mail to fill out an online questionnaire. The mean working experience in their particular field was 12.5 years for the product development engineers and 13.5 years for the artists. All participants had equal or more than 1.5 years of working experience. It is important that all our subjects had experience in their field because it is shown, that experts and non-experts disagree in their judgements of creative products (Golann, 1963; Knapp and Wulff, 1963). Therefore it is sensible to assume that in order to give definitions, actions and achievements in a certain field one has to have a certain expertise otherwise irrelevant criteria will be stated.

Questionnaire
In order to answer the question what defines creativity in the domain of product development engineering we used the method of qualitative content analysis (see Mayring, 1995). Mayring (1995) states that at the beginning of every research there should be a qualitative step in order to know what the field of research exactly is. Hocevar (1981) states that most of the measurements of creativity that identify creativity “by indirect methods (i.e. predictors) that essentially have little to do with the real criteria of creativity” (p.193). Insofar it is sensible to ask first how creativity in the domain of product development engineers can be described and what are the critical elements. After the initial question of writing down their own definition of creativity in their domain, we asked to have distinct examples of creativity in their field of expertise.
Flanagan (1954) has invented the critical incident technique in order to get concrete behaviour as data. An "incident" is best thought as "any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act." In order for the incident to be considered "critical," it "must occur in a situation where the purpose or intent of the act seems fairly clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects." (Flanagan, 1954). Hocevar (1981) is emphasizing the value of inventories of creative activities and accomplishments as the best measure of creativity. The way the questions were asked could be the starting point for an inventory of creative activities in the domain of product development engineers. In addition Amabile (1982) showed a high validity of peer-review rating ("consensual assessment") of creativity in different disciplines. This means within disciplines creativity can be identified even when the criteria are not defined on a super-disciplinary level. Another interesting question is if participants can distinguish between creativity and other constructs like intelligence or achievement. Discriminant validity would show that the given answers are effectively describing creativity and not just successful actions of product development engineers. Some research has already been done on the question of discriminant validity of creativity judgements (Holland, 1959; Mullins, 1964; Karlins et al., 1969). It seems that judges have some trouble to discriminate creativity from other constructs because in the studies conducted high correlations between the different rated constructs could be found. It is obvious that a “halo” effect (Thorndike, 1920) is present when creativity is based on subjective judgements. Rossman and Gollob (1975) demonstrated that subjects are able to discriminate between creativity and intelligence when given anonymous diverse information about the to be rated individuals. Since we are asking to describe and not judge creative actions and achievements of colleagues it may possible to overcome the “halo” effect found by judging others. To control this effect we asked for a description of a businesswise successful product development engineer. The goal of this study is to identify relevant categories for the definition of creativity in the field of product development engineering and to show that they are different to relevant categories of creativity in other domains, e.g. arts.

RESULTS
The first question for all subjects was to describe their own definition of creativity. In the content analysis we could find distinctive categories in the answers of the two groups: product development engineers and artists. Because of the low number of participants in the group of artists the results for this group can only be perceived as a preliminary trend. The following table shows the categories found.
### Table 1. Described Categories of Creativity for Product Development Engineers and Artists

<table>
<thead>
<tr>
<th><strong>Major categories</strong>*</th>
<th><strong>Product Development Engineers</strong></th>
<th><strong>Artists</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding solutions</td>
<td></td>
<td>Self-realization</td>
</tr>
<tr>
<td>Generating innovation for their field</td>
<td></td>
<td>Invent new things out of oneself</td>
</tr>
<tr>
<td>Getting/Having freedom (of thought) to be creative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing solutions/ Transform the idea to a product</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Minor categories</strong>*</th>
<th><strong>Product Development Engineers</strong></th>
<th><strong>Artists</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Team/Other people needed for the creative process</td>
<td></td>
<td>Realization of the idea (by oneself)</td>
</tr>
<tr>
<td>Know-how is needed</td>
<td></td>
<td>Creating something new on demand</td>
</tr>
</tbody>
</table>

* As major categories are labelled statements that are given in more than 80% of the answers. Minor categories are statements provided more than twice.

Following definition of creativity could be derived from the content analysis. In product development engineering it is important to find solutions to a given problem and to be able to transform the new ideas into a new product. Whereas it is important to have new ideas and create new products, the newness is relative. It is often mentioned that those inventions must be new to the according market but not necessarily absolutely new. Innovation is “something new to our market, but it could be existing in another market already” (original citation). Interesting is the category of “freedom of thought”. Hereby participants describe the importance of having freedom to work on their ideas and thoughts unhindered by management. Other mentioned statements could be summarized in the category of “Team/Other people needed for the creative process”. Here participants described the need to have sparring partners for discussion and a good team environment in order to create something new. Another category which could be found was the “expertise / know-how”. Interesting enough this category was not among the major categories. Therefore it seems that know-how is not something striking important for creativity in the field of product development engineering.

Categories drawn from the statements of the artists are differing distinctively from the categories of the product development engineers. Self-realization was the predominantly mentioned answer to the question of how creativity is defined. Product development engineers do not mention this perception that personality is the origin of the creative process. In contrast they mentioned mostly a given (technical) problem as the starting point for creativity. In the minor categories two aspects are found which resemble two major categories for the product development engineers: “realization of the new idea” stated by the artists could be compared to the “implementation” category and the category of “creating something new on demand” could be compared to “implementing the
solutions/transform the idea to a product”. But different to product development engineers for the artists these categories are not predominant.

One concept that both groups share is the concept of newness. Creativity is obviously associated with coming up with something new equally for artists and engineers.

To further detail the perceived concept of creativity we asked for critical incidents (concrete actions) in their last encounter of a creative achievement. There are clear descriptions of concrete actions or ways of thinking for both groups. The following table gives an overview.

<table>
<thead>
<tr>
<th>Product Development Engineers</th>
<th>Artists</th>
</tr>
</thead>
<tbody>
<tr>
<td>To think differently</td>
<td>To invent and make something new</td>
</tr>
<tr>
<td>Analyse the problem and take time</td>
<td></td>
</tr>
<tr>
<td>Discussing with colleagues</td>
<td></td>
</tr>
<tr>
<td>Integrate new and established know-how, products or processes to invent something new</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Critical Incidents of Creativity of Product Development Engineers and Artists

Whereas product development engineers are talking of existing or given problems to be the starting point for their latest achievements, artists are describing in their last creative achievements to over 60% that an own idea and not a given assignment was a starting point for their creative achievement. The definition criteria of self-realization for artists and the given assignments for product development engineers are affirmed with the data from the second question.

Noticeable is the different amount of derived categories between the two groups. Product development engineers describe their behaviour in various stages of acting: thinking differently, analyzing the problem (and taking time for it), discussing it with colleagues and integrate established know-how in order to come up with something new. Artists in contrast have only one category of behaviour: inventing and making something new. It is not identifiable from the given examples of situations and behaviour why the difference exists. But one interpretation could be that because of the self-realization concept of artists, creativity is seen as something holistic that is not separable in different behavioural aspects.

The description of a concrete creative behaviour reveals some additional categories of creativity that were not mentioned by the entire group or not mentioned by the majority of the participants in the first question. The reason for this could be as Flanagan (1954) emphasizes that due to the critical incident technique categories can be found that are not given in a globally asked question. These new categories seems to be not important for a general definition of creativity in the subjects mind but they are describing the actual behaviour if somebody is acting in a creative way. Therefore they have to be included into the definition of creativity if one wants to improve selection and training for product development engineers regarding creativity.

In a third and fourth question we asked if the subjects could describe a creative and a successful engineer or an artist of those characteristics. The data from the artists could not be used due to missing data. The categories for the product development engineers are listed in the table below.
<table>
<thead>
<tr>
<th>Creative Product Development Engineer</th>
<th>Successful Product Development Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating ideas</td>
<td>Being goal-oriented</td>
</tr>
<tr>
<td>Accepting not limits</td>
<td>Being strategic</td>
</tr>
<tr>
<td>Having a lot of Experience / Expertise</td>
<td>Finding good enough solutions</td>
</tr>
<tr>
<td></td>
<td>Thinking in a sharp way</td>
</tr>
<tr>
<td>Tinkering a lot</td>
<td>Approach to people and having influence on them (in a positive as well as negative way)</td>
</tr>
<tr>
<td>Absorbing a lot of data and to use it to come up with something new</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Characteristics of a Creative vs. a Successful Product Development Engineer

A creative product development engineer is described distinctively different from a successful product development engineer. Only one answer was given suggesting that a creative and a businesswise successful engineer is synonymous. Thus it is shown that there is indeed a well-defined perceived concept of creativity for the domain of product development engineers.

Creative product development engineers are described as “generating a lot of ideas” this is supporting one classical assumption about creative behaviour, ideation processes. “Accepting no limits” is another behaviour described as distinctive for creative colleagues. Here it is often mentioned that these engineers seem to hate limits, do not accept them and try to go beyond them. Breakthrough thinking or “thinking differently“ was already mentioned as an important determinate for creative product development engineers. Thinking in general is also mentioned for the successful product development engineer but in a totally different meaning. Here it is not understood as a broad approach in the search for new ways and means but about thinking efficiently and sharp to reach the predefined goals. Goal-orientation, strategy-orientation and efficient behaviour (finding good enough solutions) seems to be dominating the way a successful product development engineer is perceived by his colleagues. The creative engineer is described as a tinker and absorber of data for bringing up something new. In contrast the business wise successful product development engineer is perceived as having an approach to interact with other people. This is not always described in a positive way. It could be the case that the successful product development engineer is able to present himself in a good and loyal way to his direct managers whereas he is not employee-oriented. Other successful product development engineers were described as outgoing to people and being able to establish a good contact to employees, colleagues and management.

To summarize the results a creative product development engineer could be described as follows: A creative product development engineer generates new ideas or solutions. He brings something new to his field of working which doesn’t have to be a radical innovation but it has to be new for his market. He is doing this while thinking differently on the (mostly) given problems and not accepting the seemingly given limits. His expertise is to use established know-how, products or processes and through combination produce something new. He is working quite a lot by himself, e.g. tinkering. But the discussion with a team or individual other persons plays an important role in the creative
process. One framework condition seems to be sine qua non: he needs the feeling of having the freedom to think freely.

CONCLUSIONS
With this study we wanted to get more information about domain-specificity in the concept of creativity. We assumed that domain-specificity of creativity would lead to different described categories for product development engineers and artists. Feist (2005) and Kaufmann and Baer (2004) reported differences for the domain of science/mathematics to other domains of creativity (e.g. arts). In this study further evidence for domain-specificity was found. Described creative behaviour of product development engineers did not match described creative behaviour of artists. Due to the small sample size for the artist group there is some limitation to the validity of the results. Further research with bigger sample sizes should be conducted.

Also, further research should be done to define more clearly the boarders of domain-specificity. How connected, similar or distinct is the domain of product development engineers to the domain of mathematicians or scientist in research organizations. This would provide more clarity and would therefore help to reduce the fuzziness of the term domain.

The study is limited as already stated by the small sample size. Further research should definitely be done with bigger sample sizes. Also, it is suggested by the authors to build up on this study by using the critical incident technique and coming up with an inventory for creative behaviours and achievements as Hocevar (1981) suggested. By observation and peer descriptions additional data could be obtained. A further glimpse on the results shows an interesting point regarding the discriminant validity of the concept creativity. Can creativity be described distinctively different from other concepts? The participants choose different behaviour and attitudes to describe a creative product development engineer in comparison to a successful product development engineer. Therefore we can assume for the derived categories of creative product development engineers that they are distinguishable from other constructs and personality attitudes.

Looking at the target of this study to use the results for implications for training and selection of product development engineers, there is a number of consequences that can be drawn. A lot of trainings and creativity methods focus on idea generation. This seems sensible looking at the perceived critical incidents for a product development engineer. Still it is not enough for improving creativity skills and in the end the innovation capability of product development engineers. In fact the results of this study suggest that a lot more competencies have to be incorporated into trainings for product development engineers. Communication with others and using teamwork for creativity is nothing new in the management literature (e.g. Goffin and Mitchel, 2005) but besides the call for teamwork in creative processes almost nothing has been done to research how a good communication and teamwork training should look like. Another training issue should be to improve the cognitive skills of product development engineers. In the self-perceived criteria and the critical incidents it has been stressed that thinking differently and integrating established know-how and new thinking into innovation are characteristics of a creative product development engineer. Therefore training should consider fostering integration and new ways of thinking. It seems that this goes often hand in hand with
discussions, tinkering or beforehand a thorough analysis of the problem. Analytical skills such as to describe a problem, to analyze the different parts of a problem and to be able to take different points of views in describing the problem should also be part of a training program. Tinkering seems to be something one has or hasn’t. But there is maybe a way to enhance the acceptability of tinkering in work places. Training should be done not only in a classroom environment but should also have “tinkering” subjects where people not only learn something but also learn to work with trial and error. Methods of training therefore should help the taught lessons and be congruent with it. Another important training issue will be enhancing know-how of the actual field of working for the product development engineer. This also should be done not only in a classroom environment but also enriched with a variety of practical elements, e.g. apprenticeships, technical mentoring.

Another conclusion one could draw out of this study is not so much for the training of creative potential but for the leading of product development engineer departments. If one compares the results of the critical incidents of the creative versus the successful product development engineers it can be seen that creativity has undirected components. Creative product development engineers are “tinkering”, absorbing a lot of data” but do not care about efficiency or effectiveness of their behaviour. Creativity needs “some freedom of thought”, whereas successful product development engineers are working focused, goal-oriented and cost-efficient. For a company to stay successful in the market both types of engineers are needed. For a manager of product development departments it is important to use the potential of both types. It seems that in companies more so-called successful product development engineers are promoted. Therefore it is extremely important not to hinder creativity within the organization and that the managers of product development departments are supporting the creative process in general. They should use their obvious skills in the interaction with others to support and develop even those engineers who do not share their own approach rather than being competitive. One HR-strategy for selection and promotion could be to enhance the awareness of both types of product development engineers to their differences in order to build up a mutual acceptance within the department but also within the company.

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Erlbaum Associates.


