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TOWARDS ASSESSMENT AND DEVELOPMENT OF INDIVIDUAL CREATIVITY IN ENGINEERING

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ABSTRACT

This paper elaborates on how to assess and develop individual creativity in the context of a company’s capability to innovate. An in depth literature survey shows the important individual pre-requisites for creativity are: personality traits (including motivation), neurological basics, expertise and creative thinking skills. All these elements could be assessed in four levels: 1. To what extent has a person these prerequisites? 2. Is a person aware of this? How does his self-perception look like? 3. Did he receive education, training or experience in fields relevant to creativity? 4. Can he successfully apply his abilities in a given exercise?

This classification serves as a framework for the usability and benefit evaluation of creativity tests described in literature. We come to the conclusion that there are useful tests available to measure at least some aspects of individual creativity. Nevertheless there is no objective overall performance figure like a “Creativity-Quotient” which is widely accepted. Even more important is that there is no sufficient knowledge about how to train and develop all pre-requisites of creativity and creativity itself. We identify this as an important need for research.

Keywords: Creativity in engineering, individual factors in creativity, personality, creative thinking, measurement of individual creativity.

1. INTRODUCTION

The capability to develop new products and bring them successfully onto the market is generally accepted as a source for competitive advantage for companies. We name this “capability to innovate”. This capability to innovate can be understood in a very broad sense including also organizational change. But we focus on product innovation and look at organizational change only as a necessary element to enable successful product innovation.

The more radical or even disruptive product innovations are especially challenging to companies (see e.g. O’Connor and Rice (2001), Christensen (2003)). One can structure the difficulties with radical product innovations in three steps:

– to have a at least one person who sees the radical innovation opportunity and develops an radical product innovation idea,
– to avoid that radical ideas are rejected in the companies (conscious and unconscious) decision processes, and
– to master higher risks in terms of technology and market during the development process.

There are many elements contributing to a company’s capability to innovate. Following Bleicher’s model of a company (Bleicher (1996)) we group these elements into structures (like organizational structures, processes, and available resources and competencies), activities (e.g. project portfolio and intelligence activities) and behavior (particular innovation culture). A majority of these elements have to be developed on company, business unit, department or team level. But at least the capability to develop
radical product innovation ideas often depend on a single person (e.g. the founder of a company or individual product engineers), who are referred to be the “creative” people in the company.

2. **Research Methodology**

The purpose of this paper is to develop a framework of how to assess and develop individual creativity. In order to develop this framework we first of all clarify our understanding of individual creativity. This is followed by an in depth literature survey on first the individual prerequisites of creativity. After the framework is set up, all kinds of assessment tools in context with creativity are examined and discussed, weather they can be applied in the context of our framework.

3. **Definition of Individual Creativity**

The capability of an individual engineer to develop radical new product concepts is referred as “creativity”. Because creativity is a word with manifold meanings (Taylor (1988) cites more than 60 different definitions) we have to choose our definition: In this paper we understand a product engineer’s creativity as the capability to identify customer problems (old or new problems, existing or potentially new costumers) and combine them with divergent solutions (technologies already used in the company or in other companies, or technologies which still have to be developed) to radical new product concepts with a comparable high chance of success. This matches the definition of Amabile (1996, p. 1154-1155) “… creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second”. By focusing on creativity on an individual level we do not intend to reject the fact that creative activities of course is also influenced by the organizational settings like team structure (see e.g. Fisher (1997)).

Following Taylor (1959, p. 54-61) there are five levels of creativity. The first three levels could be reached by anyone, who is persistent and motivated to be creative. The fourth and fifth level might be reachable by those who have rare prerequisites:

1. **Expressive creativity**: the creativity of children, e.g. child’s painting, originating from spontaneity and freedom.
2. **Productive creativity**: e.g. common technical construction exercise, the potential outcomes are strictly limited by given requirements.
3. **Inventive creativity**: including reuse of old ideas, but more freedom in choosing the problem to solve.
4. **Innovative creativity**: the creative product might change the way we live, therefore the creator needs a sound knowledge about the problems to solve.
5. **Emergentive creativity**: genius level, limited to a few exceptional personalities.

The first level in itself brings no benefits in terms of product innovation (of course secondary effects like joy or getting used to be more spontaneous could be gainful for an individual person). The second level of creativity should be taken for granted in any company active in product development. The fifth level might be so exclusive, that nobody can hope to employ such a person. Therefore, to improve a company’s capability to innovate, we focus on the third and fourth level of creativity.
4. **Individual Prerequisites for Creativity**

The following overview on the individual prerequisites for creativity serves as a basis for developing creativity assessment and development framework. Despite some authors like Amabile (1999, p.4) or Rothenberg (1990, S. 8) state that personality (except motivation) is not important for applied creativity we start with the more “inside” factors: personality traits and neurological basics. The more “visible” factors expertise and creative thinking skills are following.

4.1 **Personality Traits**

We understand personality as the individual patterns in character and behavior. These patterns might be changeable – but only in the long run and to a small extend. Additionally to a general overview we discuss two detail aspects cited as especially relevant for creativity: “intelligence” and “motivation”.

4.1.1 **General Overview**

Feist (1998) gives an overview on the findings about creative personalities in science and arts. He clusters all personality traits into four main groups: Social, Cognitive, Motivational, and Affective. The findings (regarding these dimensions): Creative people in general are …

- Social dimension: … less conventional, less conscientious, more self-confident, self-accepting, dominant, and hostile.
- Cognitive dimension: … more open to new experiences
- Motivational dimension: … driven, and ambitious
- Affective dimension: … impulsive

These findings are similar to Martindale (1989) and Simonton (1999). They showed that non-conformism, unconventional behavior, broad spectrum of interests, openness, cognitive flexibility and risk behavior are linked to creativity. Backed are these assumptions by various experiments (e.g. Harrington (1975), Macioszek (1982)).

Csikszentmihalyi (1997) has a more sophisticated view on personality: He describes the creative personality as a complex or mature personality. A creative person is defined by integration of contrasts and extremes. These extremes are part of the personality without inner conflicts. Having a lot of fantasy and being very realistic are for most people two poles of personality which cannot be integrated into one personality. To be a creative person one has to integrate these two antagonistic qualities. Overall creativity is correlated with personality traits and should therefore be assessable looking at personality traits.

It is discussed in literature that a creative personality is linked to a higher likelihood of mental illness. For example low “latent inhibition” (the “tendency to have … many things on your mind at the same time” e, p. 165) contributes to creativity (Carson et al. (2003)) (via the “openness to new experiences”) but also relates to psychiticism, schizotypy and trait anxiety/neuroticism (for an overview on LI-research see Rammsayer et al. (2000)).

This connection might lead to the assumption that it is not healthy to be creative – and therefore not ethical to train employees in being creative. Fortunately Rothenberg (1990)
has shown, that there might be pre-requisites which foster both (creativity and madness). The creative process itself is healthy and eventually even effective as therapy.

4.1.2 Motivation

The importance of motivation is stressed in nearly every publication on innovation and creativity. Schweizer (2006, S. 168) presents the most elaborated model on motivation: she divides intrinsic motivation to generate novelty in “need for cognition”, “mastery needs”, and “achievement needs”. These three different needs promote creative behavior to different extents: “need for cognition” promotes the first, “mastery need” the first and the second step in innovative behavior. Only “achievement needs” drives a person to complete the innovation.

Motivation might also be enhanced through encouragement and organizational support. The difficult aspect about designing incentive systems is not to flaw intrinsic motivation. Since we focus on the individual prerequisites, we do not elaborate on these aspects.

4.1.3 Intelligence

The interdependence of creativity and intelligence has been controversially discussed. In a study by Getzels and Jackson (1962) a relatively high correlation between creativity and intelligence was found: r=.30. Ripple and May (1962) support this view with their findings. In contrast Wallach and Kogan (1965) have found relatively low correlations between creativity and intelligence. They changed the character of the tests and had no time limits in their test setting. This lowers the correlation between creativity and intelligence remarkably.

Jäger (1967) compared 63 creativity tests. In his results he distinguished four areas: speed of processing, memory, creativity and processing capacity. Creativity therefore seems to be a basic dimension in intelligence. König (1981) backs these results with his study. He could extract in his factor analysis a defined factor “Idea richness” next to speed of processing, memory and processing capacity. Intelligence and creativity seem to melt into one measurable concept of overall intelligence if measured in some “overview”-context like motivation or personality.

Nowadays it is widely accepted that intelligence is a threshold for creativity. While a creative person does not need to be a genius, creativity needs a certain amount of general intelligence (Sternberg (1995), Guilford (1967)). In contrast to established IQ-tests there is not a testable “CQ”. But also IQ-concept has been criticized (e.g. by Gardner (1999)) to ignore the multi-dimensional character of intelligence.

4.2 Neurological Basics

Sperry et al. (1969) showed by working with split brain patients (at that time split brain surgery was used to cure strong epilepsy), that the left and right side of the brain can work independently, but process different information. “…, the left hemisphere is responsible for most aspects of communication. It processes hearing, written material and body language. The right hemisphere processes images, melodies, modulation, complex patterns such as faces, as well as the body’s spatial orientation.” (Kraft (2005, p. 20)).

Guilford (1967) has introduced the difference between convergent and divergent thinking. Convergent thinking is described as a logical way to solve problems. Divergent thinking is not narrowing down possibilities but invents possibilities, opens up the horizon and gives new perspectives. These two thinking modes have been
identified to be mainly located in the right brain (divergent) respectively in the left brain (convergent thinking). Creativity, especially level 3-5, needs both thinking modes.

Another neurological ingredient of being creative is a high dopamine level (which causes positive emotion during creative processes, Flaherty (2005)). Witelson et al. (1999) postulate that highly creative humans have a different brain anatomy.

All these elements have in common, that they are objectively detectable, e.g. by MRI. But the contribution of these elements to the complex process of creativity is far from being understood. Brain anatomy and dopamine level might be genetically predetermined. But we know from rehabilitation of apoplexy patients, that the brain can be trained and recover functions, that have been lost through physical damages. So when neurological training is possible for skills like “speaking” and “reading” – is it also possible for the complex process of creativity and how?

4.3 EXPERTISE

Amabile (1999, p. 5) defines expertise as follows “Expertise encompasses everything that a person knows and can do in the broad domain of his or her work.” The importance of knowledge for innovation has also extensively been elaborated by the important literature stream dealing with knowledge and competence management (e.g. Prahalad and Hamel (1990), Leonard-Barton (1995)).

It is important to see, that many inventions do not occur within one domain of expertise but through the unusual combinations of two domains. So besides having a sound expertise also the attitude in collecting and interpreting new information is absolute relevant. Read (1955) cited in Davis (1999, p. 44) describes creative people as “…juggle scraps of knowledge until they fall into new and more useful patterns.” Gluck (1985) names the “ability to combine, order or connect” as most important for creativity.

This aspect is also influenced by the two other groups of personal prerequisites: the step of information collection and problem interpretation is the first step of a creative process – and therefore described as a creative thinking skill. The perception of information, which is useless on first sight but eventually the key to big step insights, depends on personality more precisely on low latent inhibition.

Sometimes too much expertise is seen (contrary to what is said above) as a handicap in being creative. The problem lies not in the expertise itself but in the decreasing flexibility of thinking. Terninko et al. (1998) describe that children (who naturally have a low expertise) are capable of connecting all kinds of ideas to each other while common adults find only a few connections and these almost only in conventional ways.

To assess creativity in terms of expertise, we have to keep in mind that not only the pre-existing expertise is relevant but also the attitude to build up new expertise by combining information and concepts and being flexible.

4.4 CREATIVE THINKING SKILLS

Even if creativity seems often to be just a flash of intuition, creative thinking is likely more the result of an elaborate and long-term process. The creative thinking process can be described by five steps, which have might not occur sequentially, but should appear to some extent in every creative exercise (see also Funke (2000)):
- Preparation: It is shown that without deep knowledge of the issue most of the people do not create innovative ideas (Ericsson (1996), Csikszentmihalyi (1997)).

- Incubation: It is often reported that letting loose, this means changing the focus of attention to another topic, problem etc. can help to solve the original seemingly unsolvable problem. It is known that while resting our brain is still working on the unsolved problem. Finke et al. (1992) are talking about “creative cognition”. These cognitive processes cannot be influenced by will and are processed unconsciously.

- Realization: In this step the “heureka”-moment happens. The two levels before are not linked in the public opinion to creativity but there are nevertheless the ground for creative and innovative ideas. All the knowledge, expertise, motivation to learn and invent and the cognitive processes are peak in this one moment of realization how it will function.

- Judgment: Here the really realizable ideas are separated from just nice ideas.

- Implementation: To create a product one has to do more than just one good idea.

The five steps above describe the creative process that is not more than just a “normal” problem solving process. So it seems that to achieve productive creativity a problem solving might be sufficient. But what are the additional ingredients to reach inventive or even innovative creativity. Rothenberg (1990) describes three specifics in highly creative processes: very intense preparation, a “Janusian” process (where the contradictions of the problem or subject are seen and felt to highest extent), and a “homospatial” process (where a new concept solving the contradiction can be formulated).

There are several techniques and methods to support the five described steps. The classic creative techniques foster creativity by supporting divergent thinking: e.g. all variants of Brainstorming or Synectics (developed by de Bono (1968), (1985), Gordon (1961), Osborn (1953)). Also methods to support information collection and analysis regarding the problem to solve, potential solutions or the evaluation of solutions may be used. To conduct the creative process as a group exercise by using creative techniques have been criticized as inappropriate and inefficient (e.g. by Weissberg (1986), Diehl and Stroebe (1987), (1991)).

Regarding creative thinking skills it is worthwhile to assess a person’s knowledge and know-how concerning the structure and application of creative processes, as well as the usability, benefits and limitations of methods and techniques.

5. CREATIVITY ASSESSMENT

Table 1: Integrated Framework of Creativity Assessment

<table>
<thead>
<tr>
<th>Pre-requisites of individual creativity</th>
<th>Personality Traits</th>
<th>Neurological Basics</th>
<th>Expertise</th>
<th>Creative thinking skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To what extent has a person these prerequisites?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is a person aware of these? How does his self-perception look like?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Did he receive education, training or experience in fields relevant to creativity?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Can he successfully apply his abilities in a given exercise?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.1 Integrated Framework of Creativity Assessment

We will use the integrated framework of creativity assessment (shown as table 1) to classify and evaluate diverse creativity tests described in literature. The framework consists of the four pre-requisites for individual creativity presented in the chapter above and four possible levels of assessment.

5.2 Application of Creativity in Given Exercises

For creativity measurement by responding to given exercises one can generally distinguish between tests that are based on language or on non-verbal aspects or figural aspects.

5.2.1 Tests Relying on Language Exercises

Most of the known tests have in common that certain language skills are necessary to be successful in it. Therefore one has to master language up to a certain point to be found creative in this kind of testing situation.

One of the best known test “Unusual Uses” is on Guilford’s theory of divergent thinking and his Structure of Intellect model. There are terms given to test persons, for example brick. The test persons have to produce as many uses for this object as possible. Creativity is measured not only on the quantity of the produced uses but also in the quantity of categories and the originality of the produced uses is also important. The answered categories building material or keeping the heat are examples for possible answers but there are not very creative. Using the brick as a sponge is more likely to be classified as creative because not everybody comes up with that answer.

Another test invented by Mednick (1962) is the Remote Associates Test. There you have to find the common thing of three given words that are only vaguely related. The assumption is that creative persons can find out the common link and therefore creativity is measured in the flexibility of the associations. Wallach and Kogan (1965) in their study differentiate between two sorts of answering methods in order to define more precisely the shown creativity. Highly creative persons seem to need some time to produce the first association but then produce more and more creative answers. Persons are not that creative regarding the quality of the association start to “fire” right on but dry out pretty soon.

A third creativity-test is invented by Schoppe (1975): V-K-T (verbal-produktiver Kreativitätstest). Six tasks have to be completed in this test. One example is name invention. The persons are given abbreviations (3-4 letters) and should invent fitting names. A global creativity index can be formed out of the six tests. This test is also relying on the Structure of Intellect model by Guilford (1967). In difference to the tests described above this test is not relying on the creativity/originality of the produced answers but on the concept of verbal productivity. The concept of originality that is the index of creativity in the other tests seems to have some theoretical problems. Originality has to be defined with rareness or a qualitative scale has to be made which could be wrong.

5.2.2 Tests Relying on Drawing Exercises

Test relying not only on verbal skills are using mostly drawing tasks to measure creativity. The language is not longer important and the level of mastery in a language therefore no longer plays an important role to define creativity.
One of the most used tests is the Torrance Test of Creative Thinking (Torrance 1966). Given Pictures have to be completed, newly arranged or newly produced.

<table>
<thead>
<tr>
<th>Torrance Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Starting Shapes</strong></td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td>Combine</td>
</tr>
<tr>
<td>Complete</td>
</tr>
</tbody>
</table>

Figure 1: Torrance Test, Source: Kraft (2005)

5.2.3 WHAT DO THE EXERCISE TESTS MEASURE

The tests presented above are meant to measure, if creative thinking can successfully be applied. But they focus on divergent thinking, which is a shortcoming – most creative processes need both divergent and convergent thinking.

General tests like these cannot include specific expertise. Context specific exercise can include this expertise – but they miss the standardized evaluation rules. Personality traits and neurological basics are somehow applied while solving standard or context specific exercises – but they are not directly visible.

The language-based tests have an additional flaw: It is possible, that language skills are dominating the creative process.

5.3 RECORD OF EDUCATION, TRAINING AND EXPERIENCE

A record of education, training and experience concerning expertise and creative thinking skills can be compiled by CV analysis and biographic interviews (see Taylor and Ellison (1964), Hocevar (1980)). One useful example is done by Richards et al. (1988). Here everyday creativity was asked for in interviews. The data was categorized. Four categories were combined to a matrix structure (intensity of engagement in creative activities/“genius creativity” and professional/recreational area).

The interviews will also include the self-perception of expertise and creative thinking skills – but it is not possible to evaluate these aspects absolutely objectively. Personality traits and neurological basics can by any chance be observed indirectly in the interviews.

5.4 MEASUREMENT OF PERSONALITY TRAITS BY QUESTIONNAIRES

It is not possible in this paper to describe all used personality inventories to measure creativity relevant aspects. As an example for measuring creativity one of the most used personality inventories are described. Whereas most other personality inventories are made for clinical issues or certain professional areas Gough (1968) has come up with an inventory (California Personality Inventory) that could be used in a wide range of
situations. The CPI is especially interesting because it deals with culture spanning personality factors. Therefore it can be used in different cultures. It is described that there are reliable results for measuring creativity (Amelang and Bartussek (1990)).

The Adjective Check-List by Gough (1979) is also known to have a good validity to measure creativity. In this adjective check-list one has to indicate which of the adjectives (e.g. capable, honest, artificial, intelligent ...) best describe him.

All personality inventories are designed to objectively measure personality traits. But they are to some extend biased by self-perception.

5.5 Measurement of Neurological Basics

Neurological basics could theoretical be assessed by medical investigations. Due to ethical and practical reasons this is not possible for example in a job interview. The self-perception of neurological basics cannot be evaluated, because people do normally have no cognition of these processes.

5.6 Resume

Table 2 summarizes the discussed assessment methods. For every group of pre-requisites are assessment methods available

<table>
<thead>
<tr>
<th>Pre-requisites of individual creativity</th>
<th>Personality Traits</th>
<th>Neurological Basics</th>
<th>Expertise</th>
<th>Creative thinking skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To what extent has a person these prerequisites?</td>
<td>Personality inventories</td>
<td>Medical investigations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is a person aware of these? How does his self-perception look like?</td>
<td>CV analysis and Biographical interviews (only indirect)</td>
<td>CV analysis and Biographical interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Did he receive education, training or experience in fields relevant to creativity?</td>
<td>Is training possible?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Can he successfully apply his abilities in a given exercise?</td>
<td>Creative Exercise</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Assessment and Development of Individual Creativity – Conclusions

There are useful assessment methods available to measure at least some aspects of individual creativity. These tests might be used to optimize the Human Resources in terms of the company’s capability to innovate. Especially relevant Human Resource decisions are: employment, promotion and training.

6.1 Employment

Prior to choosing the proper creativity test for a job interview or assessment, it has to be identified to what extend creativity is important for the open position.

We recommend using:

- Biographical questionnaires resp. interviews: As described by Schuler (1992) biographical interviews are standard in job interviews. Normally they are not
focused to creativity. Additional questions regarding creativity have to be integrated.
- Case studies: concerning the job context can be used to evaluate creative thinking skills and expertise in the same exercise
  - Standard creativity tests,
  - Personality inventories.

6.2 **PROMOTION**

All assessment methods used for job interviews can be used for career planning interviews. Additionally achievements in the current position can be discussed.

6.3 **TRAINING**

By assessing the personal pre-requisites for creativity improvement potential and therefore need for training can be identified. But until now we have no sufficient knowledge whether the “inside” pre-requisites (personality traits, neurocognitive basics) can be trained. This is an urgent research need. Findings concerning creativity training could not only be used in companies, but also for the configuration of university courses in engineering.

**REFERENCE**


