Idea Engineering: Teaching Students how to Generate Ideas

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Abstract - **The ability to generate ideas for solving problems and producing innovations is undoubtedly an important skill for any engineer. Usually, this is accomplished using well-known, but generic creativity techniques. These methods tend to be unstructured and somewhat random in their approach, and there are no clear guidelines available for their application. At the University of Magdeburg, we have taken an Engineering approach to the problem of producing ideas. We have reduced the large number of published creativity techniques to a small number of fundamental principles which can provide a basis for a systematic methodology for producing ideas. Based on our research results, we have created an undergraduate course entitled "Idea Engineering" which is attended by students from Engineering, Management, Computer Science and Social Sciences programs. Students work together in teams to design and build an "idea factory" which they then apply to real-life problems supplied by industry.**

Index Terms – Creativity Techniques, Idea Engineering, Ideation, Netstorming.

OVERVIEW

The ability to generate ideas for solving problems and producing innovations is undoubtedly an important skill for any engineer. In times of growing competitive pressure, innovations are a key to economic success for most corporations.

Usually, idea generation is accomplished using well-known, but generic creativity techniques. These methods tend to be unstructured and somewhat random in their approach and there are no clear guidelines available for their application. As a result, they can be quite unpredictable, which has given "creative workshops" a bad reputation, especially among managers and engineers.

Even a brief survey of the literature on creativity techniques reveals that from an academic point of view, the field has hardly been touched. There is no unified terminology, no structure, and no theoretical basis. Small wonder then, that idea generation has not been able to establish itself in academic curricula.

At the University of Magdeburg, we have taken an Engineering approach to the problem of producing ideas. Our goal is to raise the level of idea production to an Engineering technology which can be used in practice effectively and taught to students at the University level. We are therefore closer in tone to De Bono's "Serious Creativity" [1] than to a typical playground-like approach to creativity.

In our ongoing research project, we have been able to reduce the large number of published creativity techniques to a small number of fundamental principles which can provide a basis for a systematic Engineering-type approach to producing ideas.

Once these principles have been understood, they can be used to generate tailor-made idea production techniques for any given problem. These can be considerably more reliable and efficient than the generic methods which are commonly used in practice.

Based on our research results, we have created an undergraduate course entitled "Idea Engineering". This course is attended by students from Engineering, Management, Computer Science and Social Sciences programs. Students work together in teams to design and build an "idea factory" which they then apply to real-life problems supplied by industry.

Since the ideation techniques are basically a sequence of questions and answers, they can easily be implemented on a computer. We have therefore created a software tool called "Netstorming", which allows groups of students to work together on idea production via the Internet. Students in the course use this software to familiarise themselves with the techniques, and students from the Computer Science Department have the opportunity to develop the software as part of their study program.

Together with two former students, the author has founded a company which uses the Idea Engineering technology in ideation projects for a wide variety of customers. This gives the students the added opportunity of participating in professional idea production projects and thus enhancing their understanding of the course material.

THE CURRENT STATE OF CREATIVITY TECHNIQUES

The search for ideas is usually carried out using so-called *creativity techniques*. Creativity techniques go back to the Classical Brainstorming approach by Alex Osborn [6]. Some of the most well known methods are the 6-3-5 Method, the Morphological Matrix and the Random Input Method. These and many more can be found in any popular book on creativity techniques.

More than 100 creativity techniques have been published; anyone who searches the literature will be confronted by a

bewildering assortment of methods, many of which only differ minimally. VanGundy's recent book [9] is a case in point. Furthermore, it is hard to recognise which method is most applicable for any given idea development task, and it is easy to inadvertently choose an inappropriate method and be disappointed by the results obtained. Furthermore, standard creativity techniques are generic, i.e. they are presented in a general form, and it often remains unclear how they can be optimised to a given task.

For these reasons, creative workshops and brainstorming sessions have acquired a bad reputation with many professionals – they are considered to be undisciplined and unproductive, and therefore a waste of time.

IDEA ENGINEERING

For two years, there has been a research project at the Computer Science Department of the University of Magdeburg called Idea Engineering. This project is based on the premise that idea production can be viewed as an Engineering task. Its goal is to develop both a theoretical understanding and practically applicable idea production methods. These methods should meet the criteria that characterise traditional Engineering disciplines.

We consider Idea Engineering to be a technology, and therefore prefer the term *idea production technique* to creativity technique. We refer to the graduates of the course as *Idea Engineers* and the workshop in which the ideas are produced as an *Idea Factory* (rather than "creative workshop").

In the first phase of this research project, a large number of well-known creativity techniques were analysed in order to gain a theoretical understanding of the different routes by which ideas are generated. This analysis showed that there are essentially only six basic methods for creating ideas. These basic methods can be described both simply and abstractly.

Requirements of an Engineering Discipline

With an understanding of these basic principles, tailor-made idea production techniques can be developed for each new ideation task. In order to qualify as an Engineering discipline, these techniques should fulfil (at least) the following conditions:

- **Reliability**. The methods should produce good ideas reliably, i.e. the methods minimise the probability of something going wrong.
- **Predictability**. The methods should be able to produce a given number of ideas of predefined quality using specified resources (e.g. number of participants, duration of production).
- **Transparency**. The methods should be understandable and learnable for anyone. It should be possible to explain the process of designing the idea production methods, and workshop participants should be able to recognise the purpose of the questions they are presented with.
- **Efficiency**. The methods should produce a large number of good ideas with the resources available. Idea production is a random process based entirely on human effort, so this criterion implies both maximising the human output with skilful facilitation as well as designing idea production techniques with a high signal to noise ratio.
- **Well-Foundedness**. The methods should arise from the basic principles of idea production and the properties of the task to be solved. The process of creating an idea production method should be well-defined.
- **Measurability**. The performance of the methods should be quantifiable; there are effective measures available for describing both their output and their efficiency.
- **Optimisability**. It should be possible to compare, analyse and optimise the methods. This implies that the methods have free parameters, whose influence on the output can be analysed and measured.

Such requirements go without saying in any traditional Engineering discipline such as Mechanical Engineering; for this reason, they must also hold for Idea Engineering, if the premise of the research project is to be validated. So far, we have been successful in achieving these standards, although much work is still needed in order to fully establish Idea Engineering as a well-founded field.

One example of our success in this area is that we are able to control important attributes such as the conservativeness, randomness or generality of the ideas produced. Furthermore, by adopting an algorithmic approach to idea production, we are able to measure the efficiency of our methods in a repeatable way, which is a prerequisite for optimising our techniques.

Reducing Scattering Losses

Idea production is a random process, as it relies on the associations in the minds of the participants. Different people will give different answers to questions such as "Who is a leader in their field?" or "How would Elvis Presley have solved this problem?" The answers to these questions therefore differ greatly in their relationship with the problem at hand and in their usefulness for generating a good idea. For this reason, all idea production is based on the principle of first generating a large number of raw ideas quickly and spontaneously, and then selecting from these the best ones to be improved upon.

Typical statistics for creativity techniques indicate a yield of up to 5%, in other words only one idea in 20 at best turns out to be of high quality. Indeed, one company specialising in idea production states that it can produce 58000 raw ideas in its flagship product. Assuming the customer is only looking for at most a handful of ideas, this indicates an even lower yield. By contrast, in a recent project carried out for a major international corporation using Idea Engineering technology, the participants rated 80 out of the 400 ideas produced as "grade A", which corresponds to a yield of 25%.

Change of Perspective

Over the course of time, we get to know our environment: school, college and everyday experience make us all into experts for our own personal situations. This of course has the

advantage that we can memorise solutions to known problems. These solutions occur to us quickly, often even automatically. However, when we need new solutions, our expertise is often a drawback, since we are not able to free ourselves of our established thought patterns – this is the so-called *occupational blindness* or *tunnel vision*. One famous example of this is the story of the engineers who told Henry Ford I that it was impossible to build a six-cylinder engine – to which Ford is said to have replied: "Someone find me some engineers who haven't learned what isn't possible!"

One basic requirement that Idea Engineering therefore makes of any idea production technique is that it introduces a *change of perspective* (Figure 1). This change of perspective helps us to leave our well-trodden thought paths and overcome occupational blindness. The simplest example of a change of perspective is what we call the "Random Mr. X technique". Here, we simply ask, "How would X solve the problem?" We can insert anyone at all for X, such as "a witch", "Microsoft" or "Elvis Presley". Considering how Elvis Presley might have solved the problem can yield insights that were previously unseen. Clearly, the change of perspective used will have a significant effect on the ideas produced.

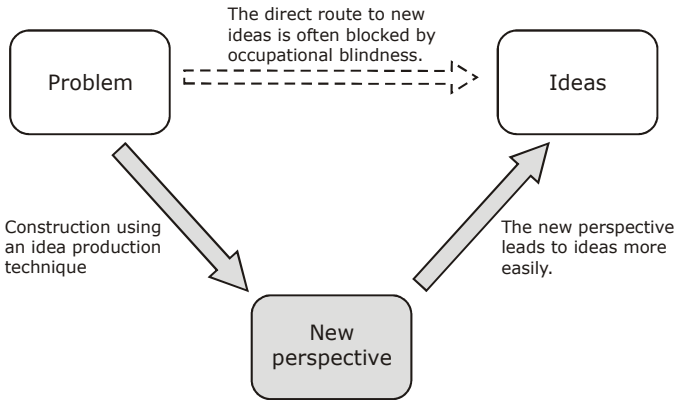

FIGURE 1
A CHANGE OF PERSPECTIVE YIELDS AN EASIER WAY TO NEW IDEAS.

Idea production techniques differ in the methods used to generate the change of perspective and in the properties of the perspectives thus generated. Examples of such properties are conservative or bold, obvious or exotic, and general or specific. Our research has shown that these properties have strong influence on the quality and quantity of the ideas produced. Remarkably, this topic does not yet seem to have been addressed in the literature on creativity techniques. A good Idea Engineer can precisely control the properties of the change of perspective, and a significant portion of Idea Engineering is devoted to finding productive changes in perspective for any given task as well as to finding appropriate questions to help workshop participants to use these changes in perspective efficiently.

All idea production techniques can be used in an idea factory in a step by step manner under the guidance of a facilitator. They can be designed very simply, and – apart from the willingness to participate in the process – they do not require any particular skills from the participants. With the right training and a little practice, the techniques become automatic and become a new type of thought process, making that person a little more "creative".

In the Idea Engineering course, students are shown the principles behind the changes of perspective and a large variety of methods for generating them. They are encouraged to develop their own techniques which should be optimised to the ideation problems given as homework assignments.

Algorithm, Format and Story

The second step necessary for making sense of published creativity techniques is to distinguish between three different aspects of idea production which are normally not viewed separately. This is a fundamental premise of Idea Engineering. We call these aspects Algorithm, Format and Story (Figure 2).

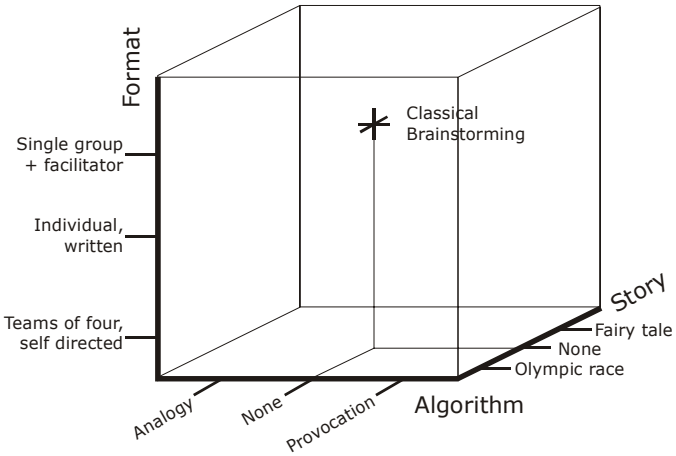

FIGURE 2
THE THREE ASPECTS OF IDEA PRODUCTION.

The Algorithm is the set of instructions for producing ideas. In the above example, this would be simply to present the problem from the point of view of a witch, Microsoft and Elvis Presley. The Algorithm is formulated independently of its implementation in the idea factory.

The Format refers to the organisation of the Algorithm when carried out. It is primarily concerned with the organisation of the participants, the role of the facilitator, and the media used. Thus Classical Brainstorming simply has the format of putting all participants in one group, who call out their ideas to a facilitator, who in turn visualises the ideas, for example using a flip chart. Alternative formats include creating smaller groups, removing (or cloning) the facilitator, and having the participants write down their ideas rather than call them out (occasionally referred to as "Brainwriting"). The choice of format can have a significant effect on the efficiency of the idea factory. Students of the course are required to choose or design optimal formats for each phase of the idea production.

A "Story" can be added to the idea production to add flavour and fun to the idea factory. Thus teams can be created which compete with each other to produce the most ideas

within a given time limit, or the idea factory can be given an overall metaphor, such as an alchemist's laboratory or a Hollywood film production. The Story is particularly useful for presenting the more challenging idea production techniques such as Provocation, where the participants are presented with hypothetical situations which directly contradict their perception of reality. In such cases, transporting the workshop to a distant planet or into a cartoon world can help free the participants' imaginations.

FIGURE 3
TEAM "BRAINBALL" USED THE 2006 WORLD CUP AS A METAPHOR FOR THEIR IDEA FACTORY.

The coordinates of Classical Brainstorming in this three-dimensional scheme are shown in the diagram in Figure 2; the format is a single group with one facilitator, no story is used, and there is no algorithm for a change of perspective. The latter property is one reason that Classical Brainstorming is often unsuccessful – the participants are expected to produce new solutions to the problem without the aid of a change of perspective. However, without the change of perspective, they can remain trapped in their occupational blindness. It takes either talent or training to be able to overcome this handicap on one's own. Learning this ability is considered by some students to be the principal benefit from attending the Idea Engineering course.

Quality control

Quality control is an important aspect of an idea factory. In a typical three-hour session, the first hour may be spent generating between 100 and 300 raw ideas. These will vary greatly in quality, precision and relevance, and must be filtered and enhanced before they qualify as legitimate solutions to the problem. Indeed, a significant proportion of them will be irrelevant or even impossible. In addition, the customer is usually only looking for a small number of good ideas.

For this reason, a comprehensive briefing is carried out. The briefing describes not only the customer's problem, but also goals, quality criteria and boundary conditions. The quality criteria are the measures by which the customer will judge the success of an idea; examples are the amount of additional revenue earned, the total costs saved or the number of new clients acquired. Examples of boundary conditions are budget restrictions or the maximum time available for implementation. In the course project, students are required to conduct briefing meetings with the customers, and they very often underestimate the subtleties involved.

The boundary conditions are integrated into the idea factories in the form of quality controls; every idea must pass through a filter which checks whether it satisfies the boundary conditions or not. The quality criteria are used to rank the ideas at the end of the session. The students in the course may not allow any idea to leave their idea factory which does not satisfy the boundary conditions.

AN EXAMPLE

We give a simple example to illustrate one method for generating ideas. The problem to be solved is to produce ideas for a local supermarket which wishes to improve service to its customers. The technique to be used is known as the analogy technique, which is illustrated in Figure 4.

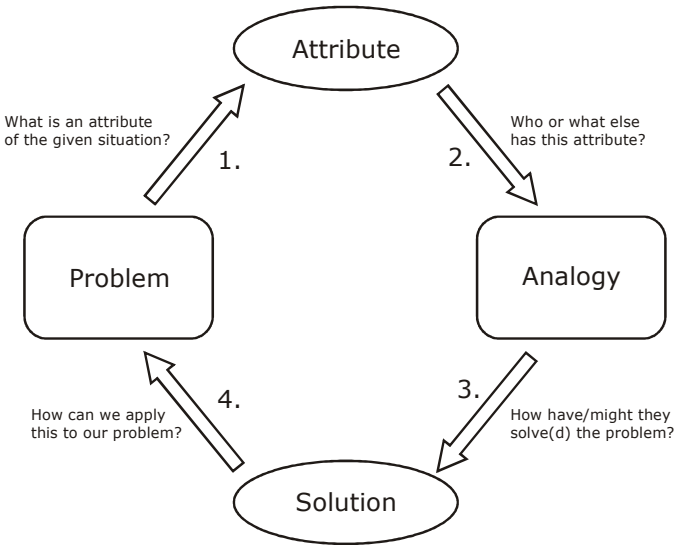

FIGURE 4
THE ANALOGY IDEA PRODUCTION TECHNIQUE

The analogy technique uses attributes of the given problem to find analogous situations. Then it is asked how the analogous problem has been or might be solved there. In the case of real analogies which are known to the participants, these answers are given from their general knowledge; in the case of unknown or fictional analogies, the answers come from their imagination. Finally, it is tested whether these solutions can be applied to the original problem. There are many methods for generating analogies, which yield very different results. The following list gives four attributes of a supermarket which were suggested during a student project:

a) A supermarket has long walls.
b) A supermarket displays a large number of items.

c) You can lose your way in a supermarket.
d) A supermarket is an important local amenity.

We now perform step 2:

a) Another place with long walls is an art gallery.
b) Another place which displays a large number of items is a museum.
c) Another place you can get lost is in a big city.
d) Another important local amenity is the town hall.

In step 3 we ask what service or solution is provided there:

a) An art gallery displays paintings for the enjoyment of its visitors.
b) A museum publishes a guidebook which provides information on its exhibits.
c) To avoid getting lost in a big city you might use a map.
d) In the town hall you can find information on forthcoming events and local groups and the banns of marriage.

The raw ideas generated are:

a) Decorate the walls with paintings by local artists or kindergarten children.
b) Publish a guidebook which gives interesting information on selected products.
c) Give customers a map of the store which indicates the major sections.
d) Display information about forthcoming events and marriages or feature local clubs and sports teams.

The required skill in this example is to choose attributes which best characterise a supermarket and thus lead to better ideas. "Often has queues of customers" is a very general attribute which will lead to a broad range of analogies and thus a large variety of ideas, and the scattering losses will be higher. "All the staff wear white coats", on the other hand, is quite a specific attribute of a supermarket, so it will yield a small number of analogies. However, since the wearing of white coats by the staff is not a particularly significant aspect of a supermarket, the analogies will probably not yield good ideas. "Offers a large variety of items", on the other hand, is a specific and important attribute of a supermarket and will likely yield a good crop of ideas via analogies such as museum, online-shop, yard sale, or Chinese restaurant.

Other idea production techniques involve similar parameters which can be tuned. In the Idea Engineering course, students learn to identify and use these in their idea factories to produce a set of ideas with the desired specifications.

FORMAT OF THE COURSE

The course offered at the University of Magdeburg currently has the format of a traditional lecture accompanied by a project. The lecture includes an introduction to creativity and creative thinking, the principles of Idea Engineering, including several examples of idea production techniques, creative problem-solving techniques, methods for evaluating ideas, and guidelines for facilitating group workshops.

Whereas the idea production techniques are presented from a unique Idea Engineering perspective, the problem analysis methods are used in a standard way, as described for example in [8] and [9].

Students are divided into teams of five, and each team has the assignment to design and build an idea factory according to the principles outlined in the lectures. Each team has a coach, who is a student or teaching assistant who has already graduated from the course. The coach meets with the team once per week to discuss the current project milestone, to answer questions and to provide guidance.

During the semester, each team must produce two prototype idea factories, which they use to test their methods and to train their facilitation abilities. These prototype milestones are accompanied by presentations, in which team representatives report on their team's progress and on the difficulties encountered and overcome.

At the end of the semester, which lasts for 14 weeks, each team is given a genuine idea production assignment to carry out. Assignments come from local companies and institutions, charitable organisations and international corporations. They include a newly-opened coffee house looking for marketing ideas, a soul band needing entertainment ideas for its Christmas concert, and the research department of a well-known corporation searching for new product ideas for some of its leading brands. The final result of the project is a comprehensive results document which is presented to these "customers" and which typically contains between 100 and 200 raw ideas and three to ten more intensively worked out solutions.

NETSTORMING: THE VIRTUAL IDEA FACTORY

By distinguishing between Algorithm, Format and Story in idea production, we are able to dispense with Format and Story and consider the Algorithms in an abstract manner. It quickly becomes clear that almost all approaches are essentially question and answer techniques. These can be easily implemented on a computer and made available on the Internet. This allows the creation of a *virtual idea factory*, in which participants log in to a server program via a web browser.

This approach has been implemented in a recent Masters thesis [3], resulting in the software tool *Netstorming*. Netstorming is used to illustrate the principles of Idea Engineering using a different format and allows students to carry out idea production projects from home or a computer lab. In addition, it provides interesting programming opportunities for students of the Computer Science Department. Idea production using Netstorming is very efficient – a group of five to six students typically generates about 200 raw ideas within one hour.

Further development of Netstorming will involve students of Psychology, who will look into the participants' behaviour online and develop methods for compensating the disadvantages of online cooperation compared to the

traditional face-to-face workshop. Also, since Netstorming stores a large amount of data during the idea production, it can be used to analyse and compare the performance of the different techniques used. By providing the means to perform controlled quantitative experiments, Netstorming is an important tool for establishing the Engineering criteria listed above.

Other software tools produced by Idea Engineering students at the Computer Science Department include a more playful version involving a genie and a crystal ball in the Story [2], and a more formal version in which the idea production methods are specified as a formal language and displayed as a hyperbolic tree [5].

KEY COMPETENCIES

Key competencies play an increasingly important role in German academic education. These competencies include giving presentations, organizing and leading teams, project management and meeting facilitation. New recommendations, both from the government and from accreditation agencies require all academic programs to provide training in these abilities, which are considered essential for a modern professional.

The Idea Engineering course is designed to provide students with the opportunity to train and experience several of these competencies. Most students find workshop facilitation the most challenging of these – they quickly discover how difficult it is to hold the attention of the participants for up to three hours, to maintain a high level of motivation, and to provide clear instructions for unfamiliar tasks.

COOPERATION WITH AN IDEA FACTORY

Together with two former students, the author has recently founded a company which carries out idea production projects for a wide variety of customers from small companies to well-known international corporations. The company uses Idea Engineering technology and involves five to ten students in each project. This gives the students the added opportunity of participating in professional idea production projects and thus enhancing their understanding of the course material.

These opportunities enhance the attractiveness of the course, since additional benefits include the chance to earn some money, to travel, and to gain experience in dealing with customers. One further motivational factor for the students is to experience first-hand the knowledge being gained in the course being applied to solve real-world problems.

CONCLUSION

Idea Engineering is the name of a research project and a one-semester course at the University of Magdeburg, Germany. Its goal is to improve the methodology for generating ideas from its current state to an Engineering discipline. Student teams have access to the latest research results via weekly lectures and are given the task of designing their own idea factories. In doing so, they both aid companies and organizations in need of innovative ideas and also contribute to the ongoing research effort.

The course is unique in bringing together students from Engineering, Economics and Social Sciences programs in teams which work together for an entire semester. Students from the "hard" Sciences must learn "soft" skills such as workshop facilitation, and students from the "soft" Sciences must learn to develop techniques according to "hard" criteria. These properties serve to broaden the students' horizons and enrich their study experience.

Students rank the course highly in University teaching evaluations and regularly praise the benefits they have received from attending. These include not only the ability to organize idea production events but also the key competencies such as teamwork and workshop facilitation which have been acquired.

Due to the success of the course, preparations are being made to extend it from one to two semesters, which will allow the students more space – both for looking deeper into research questions and for more thoroughly developing their idea factories. As of the fall semester 2006, the course will also be offered as part of an interdisciplinary Masters program.

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