Idea Engineering: A Case Study of a Practically Oriented University Course in Innovation

Graham Horton[1,2], René Chelvier[1,2], Stefan Werner Knoll[1], Jana Görs[2]

[1]Faculty of Computer Science
University of Magdeburg, Germany
graham@sim-md.de
rene@sim-md.de
sknoll@sim-md.de

[2]Zephram GbR
Magdeburg, Germany
jana.goers@zephram.de

Abstract

This paper describes a course in innovation offered to students at the University of Magdeburg in Germany. The course is based on the premise that idea generation can be viewed as a methodical discipline, and offers a unique combination of the psychological framework for creative thinking, the business background for innovation and state-of-the-art creativity techniques. The course derives much of its impact from close cooperation with an innovation consulting company and enables the students to solve real-life ideation tasks supplied by local corporations and other organizations. The paper describes the goals and design of the course, its innovative features, its reception by students and concludes with benefits and experiences gained.

1. Introduction

Idea Engineering is a one-semester undergraduate course which is given each semester by the Computer Science Department at the University of Magdeburg, Germany [11]. Its goal is to give students an introduction to ideation and innovation and contains several unique and innovative elements.

We believe that creative thinking is a valuable skill for any university graduate. Creative thinkers can produce new solutions to a wide range of problems in both private and professional contexts. Dyer *et al* [1] claim that owing to mounting pressure to innovate more rapidly, corporations are becoming increasingly interested in finding and developing innovative employees. Despite this, creative thinking and innovation are seldom contained in a university curriculum.

In 2004, the authors began to study the field of idea generation techniques. Our viewpoint was that of an Engineering discipline; in other words, we were interested in discovering to what extent the field could show measurable methods and techniques which were based on solid theoretical foundations. It quickly became clear that little had been achieved in this respect. Scientific results were fragmentary, and did not yield a unified picture. We could find no theory that explained the various methods for idea generation, and that consequently there was no taxonomy for categorizing known ideation methods and no guidelines for selecting an appropriate method for a given ideation problem. As a result of these discoveries, we undertook to develop a theoretical basis for ideation methods which would not only yield insights, but also provide concrete support for practitioners.

We named our program of research *Idea Engineering*. This title serves to demonstrate the goal of the program: to establish foundations and methods for idea generation and evaluation which satisfy Engineering criteria. The Engineers Council for Professional Development [2] defines Engineering as follows:

> *the creative application of scientific principles to design or develop […] manufacturing processes, […]; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function […].*

Our goal is that one day, idea generation and evaluation can be viewed as a manufacturing process which is based on scientific principles and which can be designed and operated to achieve a pre-defined functionality (i.e. produce the right number of ideas at the right level of quality) and whose efficiency can be measured and optimized according to reliable principles.

1530-1605/11 $26.00 © 2011 IEEE

To accompany this program of research, we created a one-semester undergraduate course of the same name. This course is offered each semester by the Computer Science Department at the University of Magdeburg, and it is open to students from all departments of the university. It is now in its tenth semester and has graduated about 250 students in total. The course is popular among students and considered by many to one of the most valuable in their respective programs.

In this paper, we will describe the design goals of the Idea Engineering course, its implementation and its most important attributes. We present responses from a survey conducted among graduates of the course which show how students evaluate its features and relevance. We discuss the experiences we have gained from teaching the course and our opinion of the benefits that it yields. Finally, we give recommendations for practitioners who are interested in implementing similar programs.

2. Overview of the course

Our primary purpose is to provide students with an innovative course in which they understand the need for innovation in modern organizations and learn how to systematically generate and evaluate ideas. Subsidiary goals were to promote soft skills such as teamwork and to give students the opportunity to participate in a university research project.

The course is composed of three distinct elements: a traditional weekly lecture format, a weekly practical exercise class, in which the students practice and evaluate the various methods presented in the lecture, and an end of term project, which is described in the next section.

The course is attended by students from the Departments of Engineering, Computer Science, Business and Humanities. No prerequisite knowledge is prescribed, and students are admitted from the second year of the Bachelor program and up. The course is completely self-contained, and requires no additional reading.

The topics treated in lectures cover three distinct areas: Innovation, idea generation and evaluation, and psychological aspects of group work. A summary of the syllabus is given in the Appendix.

Innovation is looked at from a business point of view, covering the need for innovation, types of innovation, criteria for the success of new products and services and the typical innovation process as practiced in industry.

Idea generation covers both well-known ideation methods such as brainstorming, 6-3-5 and morphological matrix, as well the new principles that resulted from our own Idea Engineering research. In addition, students learn idea generation methods from specific business fields such as for creating advertisements [3] and for new product development [4].

Psychological aspects are concerned with effects that can occur during group activities. These include such well-known phenomena as Evaluation Apprehension [15], Groupthink [16] and Social Loafing [17]. In order to plan and facilitate group tasks – in particular ones which require creative input – it is important to understand and recognize these effects.

We consider it to be a feature of our course that it covers business, creativity and psychology. We feel that this combination prepares students in a unique manner for facilitating discussions and workshops in their future careers.

The course has many features of a capstone project [5]. Capstone projects are typically found in Engineering curricula and are comprehensive, team-oriented projects which require the students to assume a large amount of self-responsibility for the outcome. The goal of capstone projects is to provide students with the opportunity gain experience, for example in:

- the application of their academic knowledge
- interacting with clients
- working together in a team
- managing a project
- designing a solution to a real-life problem

One common criticism – especially by students – of academic assignments, is their lack of relevance. This criticism has been expressed by Holcombe *et al* [6] as follows:

> *"Normal student project experiments are rarely valid because the whole exercise is something of a sham and everyone knows this. Nobody really wants the products to use in real life."*

By designing and implementing solutions to ideation tasks which are provided by real-life clients, the Idea Engineering course avoids this criticism.

3. Teamwork and project

Participating students are organized into teams of five or six for the duration of the semester. In these teams, they devise and evaluate methods for

generating and evaluating ideas and plan and execute the end of term project. Each team member has a specific role and carries responsibility for a particular aspect of the project.

For their end-of-term project, each team must acquire a real-life ideation task from the local community and design and conduct an ideation workshop based on this task. Project acquisition by the student teams is autonomous and is not subject to any restrictions. Some examples of ideation tasks that students have worked on are:

- A café near the university campus which was looking for ways to attract customers
- A local charity which wanted to raise awareness for its work
- A computer games company that needed ideas for a computer game for small children
- A cosmetics company wanting to expand its internationally known brand of skin cream
- A business hotel which was looking for ways to promote its seminar facilities
- An apartment management company that wanted to attract new residents
- A manufacturer of mobile energy sources looking for additional product features
- A civic project looking for ways to revive a declining area of the city

Student teams must interview the "clients", prepare a briefing, design and carry out the ideation workshop and write up their results in a report. The report includes the design choices for the workshop, an evaluation of the workshop, a summary of the ideas obtained and a critical appraisal of the team's ability to work together efficiently.

The project briefing is critical to the success of the project, since misunderstandings about the nature of the ideation task and the client's goals can easily sidetrack the team's efforts. For this reason, the course instructors check each team's briefing and make recommendations for its improvement. This is, however, the only occasion where a compulsory check-up occurs. The briefing contains the following headings for which clients have to provide information:

1. Background information: What is your current situation? What problems do you face? How do you think that an innovation workshop can help you?
2. Goals: What do you hope to achieve from this innovation workshop?
3. Ideation task: Please describe the ideas that you are looking for in one simple sentence.
4. Success criteria: How would you measure the quality of an idea?
5. Boundary conditions: What conditions must any successful idea fulfill?

As part of their final report, students must evaluate the results of their workshop with respect to these criteria; they must assess to what extent the ideas that were generated are useful to the client.

The workshop itself is designed and facilitated by the student teams using the knowledge acquired over the course of the semester. In addition to the facilitation team, the workshop is attended by members of the client's organization, who act as experts, and independent participants, whose role it is to enrich the ideation process. These independent participants have no expertise in the subject of the workshop and are typically fellow students. The overall number of participants in the workshop varies from 10 to 20 people.

The student teams plan and carry out their ideation projects autonomously; a coach is available to them, who provides advice if and when it is requested. Project Management is therefore an additional feature of the course. Each student in a team has a specific role for which he or she must assume responsibility throughout the project. These roles are idea generation, idea evaluation and selection, customer relations and team leader. Students choose their roles themselves as part of the first project milestone of the semester.

Many researchers have studied the advantages of teamwork-based teaching for university students. According to Marin-Garcia and Lloret [7], these advantages include acquisition of professional skills such as interpersonal communication, teamwork, group problem-solving, leadership, negotiation and time management. In addition, teamwork can enhance the learning itself. Students also state that group activities are more interesting, entertaining and learning-facilitating than traditional teaching. We have investigated student evaluations of the course via a survey, some of the results of which are given in Section 6.

4. Principles of idea generation

Our starting point for explaining ideation techniques is the SIAM (Search for Ideas in Associative Memory) cognitive model, which proposes that knowledge is stored associatively in memory [8]. This model permits an explanation of

why classical brainstorming is seldom successful at producing new ideas and provides a basis for understanding and developing more sophisticated and more effective methods.

The primary result of this approach is the so-called change of perspective as the central mechanism for generating new ideas (Figure 1).

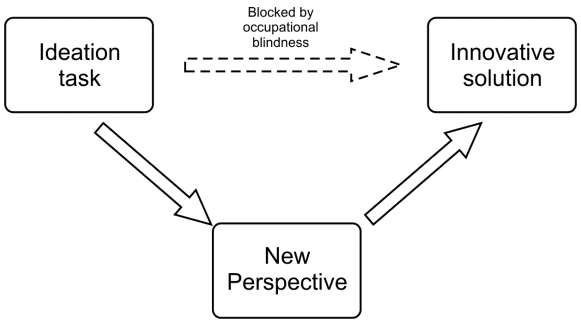

Figure 1: The change of perspective

A large number of well-known ideation methods, including classical brainstorming, do not contain a change of perspective and thus do not provide the participants with a means to overcome occupational blindness. This is the reason that brainstorming and its many relations seldom produce original ideas.

By contrast, changing one's perspective can overcome occupational blindness and provide stimuli that lead to ideas. A study by two of the authors of more than 100 published ideation techniques [9] has shown that there are essentially only three underlying types of change of perspective upon which these techniques are based, called Analogy, Provocation and Random [10, 12].

In Idea Engineering, students learn the three principles underlying the change of perspective and how these relate to the SIAM cognitive model. With this knowledge, they are able to develop their own methods for changing perspective based on the ideation task to be solved. Our approach contrasts strongly with other courses in this regard: Bull et al [13] show that usually, a large number of individual creativity techniques are taught, as opposed to the small number of underlying principles on which these are based.

One example of the depth in which we treat the change of perspective can be illustrated using the analogy technique. Although this method has been described in various collections, descriptions tend to be very superficial and do not address what we feel to be essential questions.

The analogy method proceeds in four stages:

1. Select an attribute of the given situation.
2. Name other entities which also possess this attribute.
3. State (or imagine) how these entities might solve the given problem.
4. Adapt these solutions in an appropriate manner.

Clearly, the choice of analogies in step 2 plays a central role in the effectiveness of the method, and these in turn depend on the attributes chosen in step 1. We have not been able to find any discussion in the popular or scientific literature of what characterizes a good attribute (and thus leads to a productive analogy.)

Consider the ideation task of finding ideas for a hairdresser's salon that make it more attractive to its customers. The following list gives typical attributes that might be suggested by participants in a workshop:

1. The salon has a tiled floor.
2. The hairdresser has different kinds of scissors.
3. The salon earns money by making its customers feel good about themselves.
4. The hairdresser touches the customer while performing the service.

It seems intuitively clear (and experience obtained by the cooperating innovation consultancy confirms this), that attribute #1 is too general to be of much use. The number and variety of analogies (i.e. places that also have tiled floors) is so large that generating a useful idea from them would be a fluke rather than by design. Attribute #2, on the other hand, is extremely specific to a hairdresser's salon; however, since it is not of central importance to the customer experience, ideas obtained from analogies will probably not be very effective. Attributes #3 and #4 are of higher quality, since they are both characteristic of a hairdresser and also relevant to the customer experience. For this reason, these attributes are more likely to lead to good ideas and are therefore to be preferred.

Analyses like this are an important aspect of the Idea Engineering course, since they provide students with insights into the principles underlying the various changes of perspective. This enables them to more precisely design their own ideation workshops and thus achieve a higher quality result.

5. Cooperation with a consultancy

One result of the Idea Engineering research project was the founding of a spin-off company by the first, second and fourth authors. This company is a consultancy which advises corporations in their innovation activities and applies the Idea Engineering research results on a daily basis. The company is located only a few minutes walk from the university campus.

This situation is very beneficial to the Idea Engineering course, since it provides a regular source of examples and case studies which can be used in teaching (as far as confidentiality permits). In this manner, students of the course are exposed to a wide variety of innovation and ideation problems from leading German corporations.

In addition, interested students who graduate from the course are able to work for the consulting company as freelancers. This gives them the opportunity to develop their professional skills and gain experience working together with engineers, managers and executives from the client companies on their innovation projects. We believe this is a good example of a mutually beneficial partnership between the university and business.

6. Student evaluation

The Idea Engineering course is evaluated at the end of each semester. It consistently achieves high ratings from the participating students, who emphasize the positive experience of carrying out a real-life project and the soft skills that they have acquired. Many students state that they have learned important skills which they can apply both in the rest of their studies and also in their future careers.

In order to evaluate the effectiveness of the course and detect opportunities for improvement, a survey was carried out. An online questionnaire was created, and all 250 graduates of the course over the past five years were invited by email to fill it in online. We received 104 responses from students from the Schools of Arts and Humanities, Science, Engineering, Economics and Computer Science.

Students were asked to evaluate the effectiveness of various aspects of the course in supporting the learning of the material. On a scale from "very effective", "effective", "neither effective nor ineffective", "ineffective" to "very ineffective", in all cases, the majority responded with "effective" or "very effective"). The results are given in Table 1.

Table 1: Number of affirmative responses to learning effectiveness question.

Aspect of the course	Percentage of affirmative responses
Teamwork	92%
Interdisciplinary teams	69%
Allocation of responsibilities to team members	66%
Project Management	78%
Design of an Ideation Workshop	89%
Working on a real-life assignment	73%

In a second series of questions, participants were asked about the value of the same aspects of the course in their careers. The results are given in Table 2.

Table 2: Number of affirmative responses to career effectiveness question.

Aspect of the course	Percentage of affirmative responses
Teamwork	96%
Interdisciplinary teams	75%
Allocation of responsibilities to team members	72%
Project Management	79%
Design of an Ideation Workshop	55%
Working on a real-life assignment	73%

In both cases, almost all the remaining responses were neutral ("neither effective nor ineffective"); negative responses ("ineffective" or "very ineffective") were limited to occasional single answers only.

We conclude from these results that students found that important features of the course were beneficial to them – both within the course itself as an aid to learning the material and also as career skills.

7. Experiences and recommendations

Teaching Idea Engineering has been a very rewarding experience in many ways. Students are grateful for a course which is not only theoretical, but also puts the theories taught into practice in a real-life project. Recently, students awarded the prize for the best course in the department to Idea Engineering.

The teamwork and project approach to applying the material presented in a traditional lecture format is very successful, and in addition provides a basis for training a variety of soft skills. However the necessity of working together as a team and the high degree of autonomy required for success mean that older students tend to be more successful than younger ones.

The course benefits greatly from the diverse backgrounds of the participants; teams composed of a mixture of Humanities, Business and Engineering students regularly produce more interesting results than homogeneous teams. We believe that this is due to the greater variety of backgrounds, approaches and styles to found in the different subject areas.

We have experimented with different methods for assembling the teams. One approach is to assign students to teams randomly, another is to let teams find themselves without any restrictions. A third variant is to let students compete for the roles of team leader and use the children playground selection method whereby team leaders pick their team members alternately from the pool of students in the course. As mentioned in the previous paragraph, heterogenous teams perform best, but, left to their own devices, students will tend to create homogenous teams, whose performance tends to be more one-dimensional. However, students dislike the random approach, and, unfortunately, timetable considerations often preclude the forming of inter-departmental teams.

The combination of material from Psychology, Business and Ideation provides a uniquely useful foundation for students to prepare and conduct innovation projects.

Students from the School of Arts and Humanities report that they regularly apply Idea Engineering techniques in other coursework, in particular for cultural projects they carry out in the region.

The cooperation with the ideation consultancy provides valuable case studies and real-life examples which significantly enrich the course. In addition, students who have graduated from the course and freelance at the consultancy increase the feeling of realism and applicability of the material. This is obviously a special local situation that cannot in general be replicated elsewhere.

We feel that it is very important to give the students genuine ideation problems to work on. In the ideation literature, "toy" problems are very often used; we believe that this is a serious shortcoming. Fortunately, with the advent of Open Innovation and Crowdsourcing, there are now many public portals in the Internet where real-life ideation problems can be found.

With regard to the ideation techniques themselves, we observe that students achieve a higher competence when shown the underlying principles, which allows them to generate their own techniques as needed, rather than simply being exposed to a long list of methods based on these principles.

In the same vein, we observe that having contact with genuine clients and solving a problem for them enhances the students' experience considerably. They are able to escape the "ivory tower" and are forced to deal with the real-world issues that a service provider is faced with. Artificially created assignments from the course instructor cannot yield the same benefits.

One possible extension to the current course material is TRIZ. TRIZ is a well-known, highly formalized ideation method which has its origins in solving mechanical problems. By its nature, it is consistent with the style and aims of Idea Engineering, which is confirmed by the experiences reported by Belski [14].

8. References

[1] J.H. Dyer, H.B. Gregersen, and C. M. Christensen, "The Innovator's DNA", Harvard Business Review, December 2009.

[2] Encyclopædia Britannica. Retrieved January 3, 2010, from Encyclopædia Britannica Online: http://www.britannica.com/EBchecked/topic/187549/engineering

[3] J. Goldenberg, D. Mazursky, and S. Solomon, "The Fundamental Templates of Quality Ads", Marketing Science, Vol. 18, No. 3. (1999), pp. 333-351.

[4] W.C. Kim and R. Mauborgne, "Blue Ocean Strategy". Harvard Business Review, 76–85. October 2004.

[5] A.J, Dutson, R.H. Todd, S.P. Magleby, and C.D. Sorensen, "A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses", Journal of Engineering Education, January 1997.

[6] M. Holcombe, M. Gheorghe, and M. Macias, "Teaching XP for Real: some initial observations and plans". In Proceedings of 2nd International Conference on Extreme Programming and Flexible Processes in Software Engineering, Pearson Education Inc. 2001.

[7] J.A. Marin-Garcia, and J. Lloret, "Improving Teamwork with University Engineering Students. The Effect of an Assessment Method to Prevent Shirking". WSEAS Transactions on Advances in Engineering Education, Issue 1, Volume 5, January 2008.

[8] B.A. Nijstad, and W. Stroebe, "How the Group Affects the Mind: A Cognitive Model of Ideation in Groups", Personality and Social Psychology Review, 10(3), 2006, 186-213.

[9] A.B. VanGundy, "101 activities for teaching creativity and problem solving", Wiley & Sons, Inc., 2005.

[10] S.W. Knoll, and G. Horton, "The Structure of Idea Generation Techniques - Rules for Generating Goal-Oriented Ideas", Technology for Creativity and Innovation: Tools, Techniques and Applications (Ed. A. Mesquita), IGI Global, 2010 (to appear).

[11] G. Horton, "Idea Engineering: Teaching Students how to Generate Ideas", 9th International Conference on Engineering Education, San Juan, Puerto Rico, 2006.

[12] S.W. Knoll, and G. Horton, "Changing the Perspective: Improving Generate thinkLets for Ideation", Proceedings of the 43rd Hawaii International Conference on System Sciences. Los Alamitos: IEEE Computer Society Press, 2009.

[13] K.S. Bull, D. Montgomery, and L. Baloche, "Teaching Creativity at the College Level: A Synthesis of Curricular Components Perceived as Important by Instructors", Creativity Research Journal, Vol. 8, No. 1, 83-89, 1995.

[14] I. Belski, "Teaching Thinking and Problem Solving at University: A Course on TRIZ", Creativity and Innovation Management, Vol. 18, No. 2, pp. 101-108, June 2009.

[15] M. Diehl, and W. Stroebe, "Productivity Loss in Brainstorming Groups: Toward the Solution of a Riddle", Journal of Personality and Social Psychology, Vol. 53, No. 3, 497-509, 1987.

[16] D.D. Henningsen, M.L. Miller Henningsen, J. Eden, and M.G. Cruz, "Examining the Symptoms of Groupthink and Retrospective Sensemaking", Small Group Research Vol. 37, No. 1, 36-64, 2006.

[17] S.J. Karau, and J.W. Williams, „Social loafing: A meta- analytic review and theoretical integration", Journal of Personality and Social Psychology, Vol. 65, No. 4, 681-706, 1993.

9. Appendix

The following list shows the 11 lecture topics currently covered by the Idea Engineering course:

1. *Introduction to the Course.*
2. *What is Innovation?* The role of innovation in society; Creative destruction; The importance of innovation for business; The commodity trap; Innovation goals; Famous innovators.
3. *Types of Innovation*. The corporate innovation process; Disruptive and sustaining innovation; incremental and radical innovations; Technology push and market pull.
4. *Changing Perspective I: Jumping*. Cognitive model; Analogies; Random techniques.
5. *Changing Perspective II: Pumping*. Structuring a problem; Methods for zooming in on a problem; Checklists.
6. *Changing Perspective III: Dumping*. Professional blindness; The provocation operation; Assumption breaking; Reversal; Distortion; Exaggeration; PO.
7. *Classical Creativity Techniques*. 6-3-5, Classical brainstorming; Brainwriting; Morphological matrix; TILMAG; Semantic intuition; Bionics.
8. *Clustering and Selecting Ideas*. Clustering; Filtering; Ranking; Goals and boundary conditions. Design parameters; Typical problems.
9. *Case studies*. Discussion of real-life case studies provided by the cooperating innovation consultancy.
10. *Refining and Evaluating Ideas*. Acceptance and rejection errors; Methods for refining ideas; Typical shortcomings of raw ideas; Polarising ideas; Utility analysis; Quantitative and qualitative evaluation.
11. *Psychological Effects in Group Work*. Evaluation apprehension; Groupthink; Cognitive interference; cross-cueing; Production blocking; Social loafing; Redundancy; Distractions; Social facilitation.