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What is easier to solve: open or closed problems?

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SESSION

S2: Educating the Edisons of the 21st Century

CONTEXT

Technical innovation can be roughly subdivided into two categories. A first category is concerned with solving problems that are well understood, and those problems are often formulated as a contradiction: the engineer tries to improve a parameter of a system for a certain reason, but unfortunately another parameter of the system gets worse. The second category is concerned with problems that are not known, basically the engineer tries to integrate a new function.

PURPOSE

It is the purpose of this paper to compare how easy students find it to solve the respective problem categories, and how much enjoyment they have in dealing with these, as this may influence in which order to teach respective analysis and problem solving tools.

APPROACH

Cases for each problem category were distributed to student groups to work on using a structured problem solving technique. Directly after the exercise the individual students were given questionnaires to evaluate various aspects of the exercise. The result of questionnaires was then analysed and evaluated.

RESULTS

No statistically significant difference could be established in how easy students find it to solve problems of the two problem categories. Also, no statistically significant differences could be established in the enjoyment that students had in solving problems of the two problem categories.

CONCLUSIONS

If there is a difference in how easy students find it to solve the respective problem category, then it may be prudent for a teacher to start teaching problem solving techniques that relate to the problem category that is easier, or more enjoyable to work on. However, no such statistically relevant difference could be detected.

KEYWORDS

Open problems, closed problems, TRIZ, inventive principles.

Introduction

The application of creative techniques in business is of increasing importance for companies to gain and keep an advantage over competition, as stated by Dobrusskin, Belski and Belski (2014). A number of techniques is used for these purposes, and TRIZ, the Theory of Inventive Problem Solving has, in recent years, been one of the more interesting of these techniques for both engineers and designers (Aoussat, Cavallucci, Trela and Duflou, 2013). Analogous with the growth of importance of including creative techniques into the portfolio of processes of companies, there has been a growing interest of teaching these creative techniques in education in general (e.g., Thijs., Fisser and Hoeven, 2014), and specifically in the engineering education. Belski *et al.* for example has included TRIZ in the education of students at the RMIT Melbourne (e.g. Belski, Baglin, & Harlim, 2013; Belski & Belski, 2013).

Generally creative challenges can be split into one of two categories. Firstly, closed problems, which are characterized by the fact that a specific problem situation can be well described. Secondly, open problems, which usually involve a search for something new, but apart from a crude scoping the “newness” is not further defined. This fact is recognized, for example, in the TRIZ training material of Ikovenko *et al.* (2013), by having different tools clustered to either be more suitable to tackle one – or the other of these creative challenges.

If a substantial difference can be established in how students experience the problem solving process for each of these two categories of problems, this may enable a teacher to give a student a better learning experience, for example by starting to teach a problem solving technique using the easier, or more fun technique first.

The process of solving problems has a number of different aspects. Firstly, to solve non-trivial problems is not easy. Why else would one need creative techniques to solve these problems? Consequently a problem solver will find some challenge in solving the problem at hand.

The first hypothesis that was investigated in this study was therefore to evaluate the level to which a student was challenged while solving different types of problems. Based on numerous informal experiences it reads: (i) subjects do not experience any difference in the level of challenge when solving open problems compared to solving closed problems.

Secondly, as noted for example by K. Gadd (2011), the process of successfully solving difficult problems is generally enjoyable. Again, based on numerous informal experiences the second hypothesis that was evaluated reads: (ii) subjects have the same amount of enjoyment while solving open problems as they have solving closed problems.

Definition of open and closed problems and their resolution

Particularly for open problems a number of different definitions are circulating. In the context of this investigation a specific definition of both closed problems as well as of open problems was used.

Closed Problems

The most common definition of a closed problem is that there is one correct answer to it (mathematics). Translated into the engineering domain this would mean that the set of possible solutions will be reasonably clear for an expert in the problem's domain. In the framework of this investigation a closed problem refers to a problem situation in which the problem parameters can be well described. In the industrial practice such problems are typically encountered in development or in the field. Doors for example should be constructed to close well with the surrounding doorframe. However, it the door is constructed in such a way that a finger of a child is squashed between the door and the door frame at the side of the hinges, an occurrence that is normally to be avoided, the situation could be described as a closed problem. If such a closed problem poses some intellectual challenge for it to be solved, then the problems can be described in TRIZ terms as a contradiction (e.g. Koltze, Souchkov 2011); the engineer tries to improve a parameter of a system for a certain reason, but unfortunately another parameter of the system gets worse.

In the case of said door, the problem may be formulated as a contradiction as follows:

> If the gap between door and door frame is small,
>
> Then the door will close well,
>
> But a finger may be squashed in between.

This basically states that an engineering choice, the use of a thin gap, was made in order to have a door that closes well, but that this may lead to injuring people. Thus the problem situation is well defined, and could be solved using respective TRIZ problem solving tools. For the present investigation a range of different closed problems were used.

Open problems

In contrast to this an open problem, in the context of this investigation, describes a problem situation in which the problem parameters are not well defined. Typically, those situations are encountered in an industrial environment when looking for "the next generation" of a product, or for general ideas of how a project could be improved. To keep with the example of a door, an open question could be formulated as follows;

> How would the next generation of our door range look like?

Here, apart from the time scoping, where next generation probably means within the next few years, and from the topic scoping, it has to be a door, no restrictions are given, rather new functions or new implementations of given functions are looked for. For the present investigation a range of different open problems were used.

Methodology

For finding solutions to open or closed problems a selection of the 40 Inventive Principles from the TRIZ toolbox was used. The 40 Inventive Principles and their application to problem situations is an easy to grasp way of working that can be taught within a short time span and can be applied easily to both problem categories.

A selection of 10 easy to understand Inventive Principles was made as this allows for less time to teach the basic way of working, and also less distraction on the part of the user as he or she only has to choose between 10 options, and not between 40.

Table 1: A list of the 10 used Inventive Principles

#	**Inventive Principle**
1	Segmentation
2	Taking out
3	Local quality
7	Nesting
10	Preliminary action
13	The other way round
15	Dynamics
17	Another dimension
22	Blessing in disguise
25	Self service

The inventive principles were described in a concise form. For 30% of the participants they were presented in a card format, for the remainder of the participants they were printed out on A4 sheets.

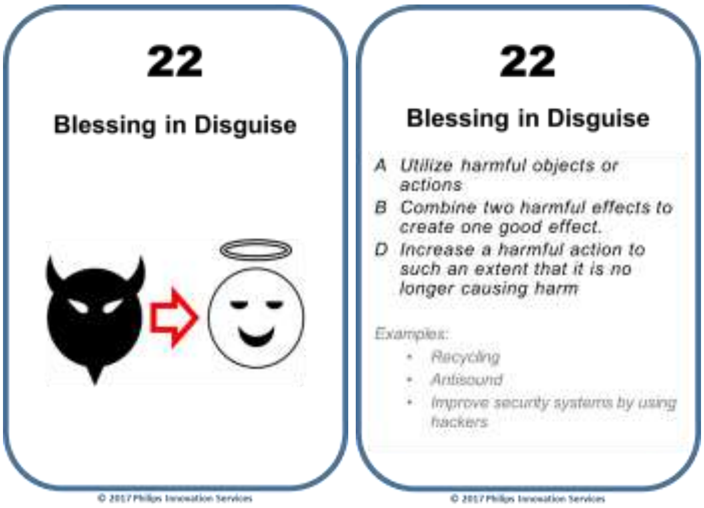

Figure 1: The card format for one of the inventive principles is shown

The way of solving both, open or closed problems using the inventive principles followed a simplified procedure compared to the classical TRIZ approach as explained for example by Altshuller et al (2005). The following steps were described for problem solving, derived from writings by Mann (2002), by Boyd and Goldenberg (2014) and by Dobrusskin (2017):

1. Describe the problem (this was given)

2. Make a list of all resources that are in or around your problem space
3. Apply the Inventive Principles to relevant resources to create ideas
4. Check if the ideas are feasible and, in the case of open problems if they are wanted/needed by the target group, or, in the case of closed problems if they solve the problem well

This procedure fits well with the needs of solving closed as well as open problems, and also requires minimal training by the participants. This greatly facilitated the research as the way of working could be explained and the problem solution process applied by the participants in as little as 40 minutes.

The process was used by a total of 61 participants from different backgrounds. 33 of the participants took part in the investigation in the EU, 28 participants took part in the USA.

Of the 61 participants, 37% were individually asked to solve the problems, whereas the remainder was asked to work in groups. 64% of the participants were first faced with the closed question, and afterwards with the open question, for 36% of the participants this sequence was turned around. The proportion of male to female participants were 80% to 20%. Most participants were Engineers (72%) with the rest divided between Students (20%) and others (8%). Only 11% of the participants had a good prior understanding or training of TRIZ, with 33% having a little understanding and 56% having no prior knowledge of TRIZ. The work experience of the participants was distributed as follows: 50% less than 10 years, 30% between 10 and 20 years and 20 % more than 20 years.

In an initial phase the problem solving process as described above was described to the participants.

They were then given a first problem, either an open or a closed one, and had to apply the process in the course of roughly 10 – 15 minutes to create possible solutions to the problem. Once they had finished the exercise, which normally meant that they had used an average of two inventive principles, they were given a questionnaire to evaluate their perception of the process.

Afterwards they were given a second problem, if they had an open problem in the first round, they were given a closed one in the second round and vice versa. Again, they had to apply the process of problem solving and take about 10 – 15 minutes to create a set of possible solutions to the second problem. Once they had finished this exercise, they again were given a questionnaire to evaluate their perception of the process, and in addition they were also asked to compare their perceptions of the first and the second problem solving exercise.

Throughout the exercises the participants had a free choice as to which inventive principle they applied. No formal evaluation of the value or quality of the created ideas was applied.

Results

The participants were positive about the helpfulness of the 10 Inventive Principles for finding solutions for both, open and closed problems. Opinions that were mentioned included the following:

- A good step for starting solution creation
- Looking forward to using this in projects
- TRIZ is systematic…

Responses to four survey questions that clarify the opinions of the team member with respect to the clarity and the helpfulness of the TRIZ principles are shown in Table 2. The table includes the question asked, mean values (M) and standard deviations (SD). Scoring is on a scale of 1 to 4 whereby 1 equals not clear / helpful at all and 4 equals very clear / helpful.

Table 2: Responses to two survey questions that clarify the opinions of the team member with respect to the clarity and the helpfulness of the TRIZ principles.

Question	M	SD
How clear were the TRIZ principles for use with closed questions?	3.11	0.45
How clear were the TRIZ principles for use with open questions?	3.13	0.65
How helpful were the TRIZ principles for the use with closed questions?	3.16	0.58
How helpful were the TRIZ principles for the use with open questions?	3.18	0.57

Responses to two survey questions that clarify the opinions of the team member with respect to the first hypothesis that formed the starting point of this investigation are shown in Table 3. Questions, mean values (M) and standard deviations (SD) are shown. Scoring is on a scale of 1 to 4 whereby 1 equals very challenging and 4 equals not challenging at all

Table 3: Responses to two survey questions with respect to the first hypothesis of this investigation.

Question	M	SD
How challenging was it to work on the exercise with the closed question?	2.11	0.58
How challenging was it to work on the exercise with the open question?	2.10	0.65

Table 4 shows the responses to two survey questions that clarify the opinions of the team member with respect to the second hypothesis that formed the starting point of this investigation. The table includes questions, mean values (M) and standard deviations (SD). Scoring is on a scale of 1 to 4 whereby 1 equals not at all fun and 4 equals a lot of fun.

Table 4: Responses to two survey questions with respect to the second hypothesis of this investigation.

Question	M	SD
How fun was it to work on the exercise with the closed question?	3.44	0.54

How fun was it to work on the exercise with the open question?	3.25	0.57

Responses to a control question asking the participants to directly compare both the aspects of easiness as well as the aspect of enjoyment of the exercises are shown in Table 5. The questions asked, mean values (M) and standard deviations (SD) are shown. Scoring is on a scale of 1 to 5 whereby 1 equals that the closed question was experienced as much easier / more enjoyable and 5 equals that the open question was experienced as much easier / more enjoyable.

Table 5: Responses to a control question are shown.

Question	M	SD
Which exercise was easier to do?	2.84	1.19
Which exercise was more enjoyable to do?	3.69	1.01

Comparing the results of the engineers with those of the students, of the male participants with those of the female participants and of the participants with lots of work experience with those with little work experience did not bring to light any statistically significant correlation on any of the survey questions.

Discussion and conclusion

The results shown in Table 2 indicate that the chosen methodology, the use of the selected 10 Inventive Principles from TRIZ, was seen as equally clear and helpful for creating ideas for closed and open problems.

Both of the stated hypotheses have been supported by the survey results. With respect to the first hypothesis (i), the responses as shown in Table 2 indicate that the participants see virtually no difference in how challenging they think it is to find solutions to closed questions vs. finding solutions to open question. The control question in Table 5 indicates that participants saw the closed questions as slightly easier to solve – and thus less challenging, however this difference is not statistically relevant.

With respect to the second hypothesis (II), the response as shown in Table 3 indicates that again the participants see little difference in how fun they think it is to find solutions to closed questions vs. finding solutions to open questions. The slight preference of 0.2 points in favor of the closed questions is statistically not relevant. This is further supported by the control question as shown in Table 5, whereby a slight preference is indicated for the open problems to be more enjoyable to work on – again, this difference is not statistically relevant.

There are a number of weaknesses of this study that should be mentioned:

Firstly, the participants were drawn from a pool of widely different ages, backgrounds and experiences. While currently TRIZ is not commonly taught in the context of a University education or the like, but instead later on during an engineer's working life, a more homogenous sample group, drawn for example from within a University context may be preferable.

Secondly, the evaluation focused purely on a self-evaluation of how the participants experienced the process of problem solving, and did not take into account the actual results they achieved. In order to evaluate if it is better for the teaching process to start learning a problem solving technique using open or closed problems, it may however be important to include some qualitative evaluation of the achieved results.

Thirdly, the problem solving method chosen may not be the optimal one. While the employed problem solving methodology based on the 40 Inventive Principles is, in the author's experience, simple to learn and powerful in application, other methods such as a Substance – Field Method suggested by Belski (2007), or the six sigma set of tools that come from the quality movement, may be equally or even better suited to fit a more experienced engineer or student. In addition, such a methods may already be included in the curriculum of an engineering study. Furthermore, problem analysis and -solving techniques have been developed that deal specifically and exclusively with either open or closed questions, and those may also be a better choice for further investigations – even if it may necessitate a lengthening of both the training of the technique, and the time allowance for solving the problem.

The results of the survey show that the problem solving process with respect to solving closed problems and open problems is experienced as equally challenging. Furthermore, there is also experienced an equal level of enjoyment when solving either closed or open problems. Notwithstanding the weaknesses of the study, this may indicate that it is not crucial to the learning process whether the teacher chooses either a closed or an open problem for teaching problem solving techniques.

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