Improvement of Thinking and Problem Solving Skills of Engineering Students as a Result of a Formal Course on TRIZ Thinking Tools

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Abstract
Forty two engineering students at RMIT were enrolled into a course on Theory of Inventive Problem Solving (TRIZ), which was conducted over 13 weeks in semester 2 2006. Results of the student surveys show that most of the students' perception of their abilities in problem solving changed vastly as a result of the course. Students reflected that they would never have expect themselves to come up with the ideas they though of and suggested while conducting their final project if they had not been properly taught the tools of problem solving.

Key words: Thinking, problem solving, TRIZ

1. Introducition

1.1 Challenges of engineering education in the 21st Century

Over the last fifteen to twenty years the engineering profession has changed vastly. This change requires engineering education to adjust to the new conditions and the new requirements. The following are the three challenges, which request engineering educators to seriously consider introducing thinking and problem solving tools into the curriculum.

The natural life of products shortens every year. Sony, for example, releases over 5,000 new products a year. Some of these new products make the existing products, which are often only a couple of years old, obsolete. This shorter life of products is gradually putting the product development time down. Drug manufacturers, for example, have already reduced the development time of new drugs by over two times – from ten years to four. Shorter development times put pressure on engineers and scientists to deliver novel solutions quickly.

Moreover, engineers of the 21st Century are facing very different challenges to what they were just 20 years ago – more and more problems they face become open-ended. In the words of Charles Handy, "Life seems to be a succession of open-ended problems with no right answers, but problems, nevertheless, which demand an answer" [1]. In other words, engineers now have to find solutions to the problems they have never experienced before, with solutions which might be unheard of.

Another challenge in educating engineers is related to the amount of information created in fields of science and engineering annually. It already exceeds what an ordinary engineer is able to comprehend and the rate at which new information is created is rapidly growing. It is practically impossible to teach all these new things during the four years of the engineering degree.

All these factors: the need to be able to resolve problems quickly, the ability to consider open-ended problems, as well as the ability to cope well under the information overload, put an engineer under unfamiliar pressure. It is expected that engineers and scientists would be capable of coping with this pressure much more efficiently if they acquired advanced thinking and problem solving skills.

In his profession, an engineer is expected to create new products and to resolve problems related to existing products. A lack of formal education in thinking and engineering problem solving means that trial and error is the most widely used approach in day-to-day engineering work. It is also common for an engineer to use brainstorming and deploy various analogies when faced with a problematic situation [2]. These approaches to problem-solving are not systematic. The thoughts and actions of an engineer using trial and error are unstructured, so

the result of the thinking process is unpredictable and is heavily dependant on the personality of the problem solver and his experience. This explains why in the opinions of engineering managers, thinking and problem solving skills are evaluated as one of the most important skills of an engineering professional. As it has already been pointed out, these skills are becoming even more vital in the extremely competitive world of today, when a delay with a product launch or erroneous engineering design may result in a company loosing its market forever.

Consequently, engineering education requires changes, which ensure that engineers of the next decade will be able to quickly and flawlessly deal with open-ended problems, which often occur under uncertainty and with considerable information overload. To achieve this, engineering graduates need to be more creative – they must become more systematic in their problem-solving work, they need to think better.

1.2. Importance of thinking and problem-solving skills

Thinking is defined as using the mind "*to consider something, to form connected ideas, to try to solve problems…*" [3]. Over the years, many authors have investigated the skills of problem-solving and creativity [4-6]. They have suggested that in order to be able to approach open-ended problems and to do it efficiently, a practitioner needs to improve his thinking skills. Moreover, they found that those thinking skills can be taught [5, 6]. Furthermore, it has been found, that teaching children to think effectively impacts on everything they do, including their learning skills [7]. Recent educational assessments have concluded that "among other things, students lacked basic critical thinking skills" [8]. Therefore, more and more educational institutions introduce thinking tools to students. This is accomplished both by embedding thinking tools into the existing professional courses and by offering separate stand-alone thinking courses. The former approach can be used with thinking tools which do not require sufficient time to learn (e.g. Random Word, Brainwriting, Six Thinking Hats). Some thinking tools, though, require extended time to learn (e.g. Substance-Field Analysis, Morphological Box, Method of the Ideal Result). They are unsuitable for embedding into existing discipline-based courses and need to be taught separately. This increases interest in stand-alone courses on thinking and problem solving. In 1993 over 800 colleges and universities in the USA offered thinking courses to their students [9].

Scholars model thinking processes by emphasising various aspects of cognition. They have subdivided thinking into many areas: systematic thinking, systems thinking, critical thinking, lateral thinking, wishful thinking, big-picture thinking etc. [10-12]. Researchers have also proposed various thinking tools to improve human thinking [2, 5, 6]. However, data on whether different thinking tools suit different professions better than others are ambiguous.

Critical thinking has been the focus of educators over the last few decades. Thus, most of the published results are related to the outcomes of courses in critical thinking. Carr has found that while teaching thinking as a separate skill is useful, it develops best when learnt in connection with a specific domain of knowledge [13]. This reinforces the likelihood that different professions require different thinking tools to enhance their thinking skills.

Our recent experience of teaching thinking and problem-solving to engineers show the effectiveness of the thinking tools of TRIZ. Results of the training programs conducted to engineers working for the companies in Australia and Singapore indicate that not only have the problem solving skills of engineers been enhanced, but the course has also helped engineers to use their existing knowledge more effectively [14-17].

The following is a reflection of an engineer from Singapore, who was involved in learning TRIZ thinking tools for six months [17].

> *"After spending six months trying to understand and adopt the TRIZ problem solving methodology, I personally feel that it is an innovative thinking process which*

effectively reduces the traditional thinking process. Through our educational system, we have been taught/brainwashed on how to solve problems with the correct solution. We are always eager to look for the correct answer, and most often neglecting the minor details which are critically related to the problem. With the help of TRIZ, I began to understand the importance of looking at a task from a wider perspective, recording down the thinking process and generating a more discipline and systematic approach when it comes problem solving, and this is especially beneficial when it involves a complex system.“

This reflection as well as opinions of many engineers involved in TRIZ training programs, identified the need for a formal university thinking course to boost thinking and problem solving skills of future engineers.

2. Method

Forty two engineering students, in their second to forth year of study, were enrolled in a RMIT-wide elective course “Systematic and Inventive Problem-solving” in the second semester of 2006. During the 13 weeks of the semester they studied the following four thinking tools of TRIZ: Situation Analysis, Method of the Ideal Result, Substance-Field Analysis, 40 Innovative Principles with the Contradiction Table [18, 19]. Every student had to complete four individual assignments, which were related to individual thinking tools and participate in group project work over a three week period. The projects undertaken by the student groups were related to various needs of the Australian community. The following are some of the project titles: “Improving safety of traffic lights”, “Getting rid of cane toads”, “Detection of rip currents”.

The project had to be conducted using the Seven Steps of Systematic Thinking [14].

3. Results

The results presented here come from three different sources:

- RMIT Course Experience Survey (CES), independently conducted by the university during class in week 10 of the semester and completed by 34 students,
- Pre- and post-course surveys conducted by the author in week 1 and in week 13 of the course and completed by 30 and 32 students respectively,
- Student reflections on their achievement and experience (step 7 of the formal Project Report, completed by 42 students).

3.1 RMIT CES results

Students evaluated the course very highly. All but one of them were either strongly satisfied (25) or satisfied (8) with the quality of the course. One student was unsure. Similar opinions were expressed on the usefulness of the course for their future career (22 – strongly agreed, 11 – agreed, 1– unsure). Exactly the same was the distribution of the student answers to the question “This course contributes to my confidence in tackling unfamiliar problems” (22 – strongly agreed, 11 – agreed, 1– unsure).

The following are some of the students’ opinions:

“Course is very interesting and relevant to engineering. It should really be a core subject...” “It just makes you look at things from wider angle and from all angles. Therefore it exercises your brain to think of things you do not think of.” “The course is extremely useful in enabling a person to deal with unfamiliar problems with a systematic approach.” “... able to learn how to think and come up with a solution that seems far fetched yet possible.”

3.2 Pre- and post-course surveys results and student reflections

The following are student opinions of their ability to resolve problems they face, collected in week 1 (Figure 1, left) and week 13 (Figure 1, right) of the course.

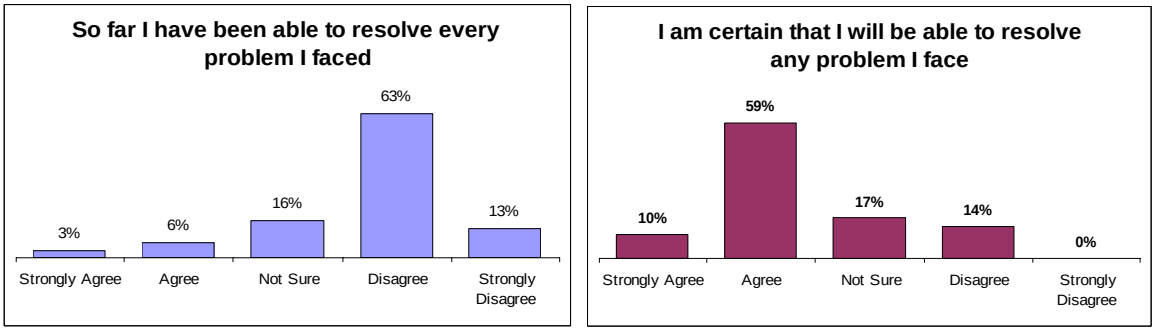

Figure 1. Student opinions on their ability to resolve problems they face: week 1(left), week 13 (right)

The data pictured in Figure 1 shows that the number of students, who were certain of their good thinking and problem solving abilities increased nearly eightfold – from 9% to 69% as a result of the course. Also, in week 1, 76% of students thought that they were unable to resolve every problem. This number went down more than 5 times – to 14% in week 13, after the course had been completed.

It is also of interest to consider a self-evaluation of the students' problem solving skills, presented in Figure 2 which represents their responses to the statement: "I am very good at problem solving". The shift from the average response of "Not Sure" to the average opinion of "Agree" is clearly visible and is significant.

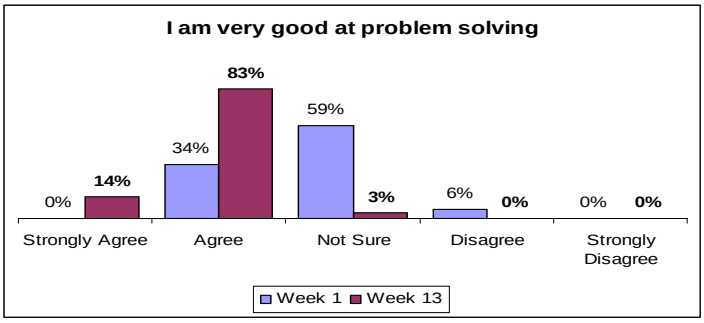

Figure 2. Change in the students' self-assessment in problem solving as a result of the course

Student opinions depicted in Figures 1 and 2 are very encouraging. They clearly show that the students' perception of their thinking and problem solving skills have improved significantly as a result of studying the tools of TRIZ and applying these tools to assignments and the project. It is, however, unclear how reliably student opinions identify real improvement of their thinking and problem solving skills. To measure this improvement some universal problem solving test is required, which the author is yet to find.

As the 14th Century proverb says there is "no smoke without a fire". Students have learnt a number of efficient tools for systematic thinking and problem solving and were able to use these tools to generate many good ideas. These, for certain, helped them to become better at thinking and problem solving. Therefore student opinions of their own abilities improved, as well as their abilities in thinking and problem solving.'

The following are the opinions of students, which further support the findings. Student opinions are grouped to highlight the changes in thinking and problem solving of students related to the three main challenges in educating engineers, identified earlier.

3.2.1 Improved ability to tackle open-ended problems

The following are quotations from the student questionnaire answers as well as from their project reflections related to their ability to deal with open-ended problems:

"I feel more confident to undertake unfamiliar problems knowing there is a systematic approach to solving the problem." "(I have developed) ability to approach unfamiliar tasks and overcome them." "I am able to see problem as a challenge, not an intimidation." "I have developed more confidence in approaching unfamiliar problems." "I have been able to learn new tools and become more confident with tackling both technical and non-technical problems." "Have the confidence to tackle new problems effectively." "(I have developed) clear thinking, ability to tackle unfamiliar problems." "(I have developed) an ability to tackle any problem." "I learnt how to tackle problems I never thought that would have been faced or solved by me." "After completing this task and the TRIZ course I believe that I am in a much better position to tackle problems in the future, both engineering related and anything else that comes my way."

3.2.2 Improved structured and systematic thinking

The following student opinions relate to enhancement of their systematic thinking:

"(I) know what to do and how to solve problems. Not just rushing to solve the problem based on experience and knowledge only." "(I) can think of unique solutions to problems." "(I gained) better systematic and analytical thinking." "(My thinking) follows a far better structure; instead of hitting my head on the desk, hoping for a solution, I have a method to make me realise a viable solution(s)." "(the course) helped me to follow a systematic way in order to solve problems." "I feel I am approaching problems in a more logical manner." "I normally attack problems to the core, now. I can at least use the tools of TRIZ to attack problems in a different manner and may end up saving a lot of time effort and understand more about the problem." "My thinking mindset has become more structured."

3.2.3 Looking beyond the current knowledge

The following student opinions relate to the changes in their thinking, which help them to look beyond the current knowledge.

"(My thinking) did change, as in, it made me think of all possibilities rather that only technical results." "(The course) just makes you look at things from wider angle and from all angles. Therefore it exercises your brain to think of things you do not think of." "Using the TRIZ tools has forced my mind to think of a problem from different perspectives in order to come up with good solution to the problem." "... my thinking ... broadened to look at previously ignored possible solutions." "My thinking changed. It helped me generate a wider range of ideas and to identify the problems." "(The course) helped me to think outside the square that I usually think in."

3.2.4 "Has your thinking changed"?

The following are student answers to the questions "Do you think that your thinking changed as a result of this course? How did it change?"

"Yes it changed my thinking because now I look at things from different angles.

Therefore, having a wider view." "My thinking in regard to the every day problem has changed. I intend to analysing the problem using the TRIZ tool, instructed in this course. Solving problems for me personally became more fun." "I personally think it will take quite a bit of time for my thinking to change 100%, however this course has definitely provided a new way of thinking that will be developed over a period of time." "Yes, it allowed me the tools to help myself in everyday as well as technical life." "Yes. I can think more effectively." "Yes. I break problems into smaller tasks now." "Yes, the ability to look at problems from a different perspective. Not always looking for the technical solution." "Yes, my thinking mindset has become more structured." "Yes, it did. Ideas are more formed neatly and ways to come up with the solution is more systematic."

4. Conclusion

The Survey completed in week 1 identified that most of the students were unaware of the existence of any formal tools of thinking and problem solving. Also many of them were uncertain that their choice of the course was wise. Nonetheless, the outcomes of the course on thinking and problem solving clearly support the opinion of engineers on importance of involving engineering students in specialised courses on thinking and problem solving.

The tools of TRIZ do not represent the best set of tools for every individual and are unlikely to help everyone in enhancing their thinking and problem solving skills. They do, however, fit the thinking needs of engineers and scientists very well. Other thinking tools, taught as a separate course are likely to make a similar impact on the thinking skills of students in other professions.

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