Introducing TRIZ Heuristics to Students in NZ Diploma in Engineering

Konstantin Shukhmin[a] and Iouri Belski[b]
Toi-Ohomai Institute of Technology[a], Royal Melbourne Institute of Technology[b]
Corresponding Author Email: Konstantin.Shukhmin@toiohomai.ac.nz

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SESSION S2: Educating The Edisons Of The 21st Century

CONTEXT Institutes of Engineers all over the world have identified problem solving and creativity as vital skills for engineering graduates to possess in the 21st Century (e.g. Engineers Australia, 2011; National Academy of Engineering, 2004). Recent Deloitte report specifically mentioned these skills as increasingly important for success of Australian businesses by 2030 (Deloitte, 2017). Research evidence of the ability of engineering programs to nurture creative graduates is inconclusive. Some authors reported on failures of current engineering programs to enhance students' creativity (e.g. Daly, Mosyjowski, & Seifert, 2014; Steiner et al., 2011).

Acquisition of professional problem solving skills is one of the main aims of the New Zealand Diploma in Engineering (NZDE). With emphasis on holistic approach in engineering education, introduction of the Theory of Inventive Problem Solving (TRIZ) heuristics could help students to be better prepared for cognitive challenges.

PURPOSE To establish whether the educational materials provided by the TRIZ Repository of thinking heuristics (OLT Fellowship, 2016) are suitable for self-learning of NZDE students.

APPROACH Sixty NZDE students from mechanical, electrical and civil strands participated in TRIZ workshops in semester 1 2017. Then they were directed to the repository of TRIZ educational materials and were asked to complete an online survey. All students were encouraged to apply TRIZ heuristics in the Engineering Project paper. The paper analyses students' feedback and investigates possible integration of the TRIZ into the NZDE program.

RESULTS A set of TRIZ tutorials and workshops with NZDE students at TOIT (Bay of Plenty, NZ) has revealed their genuine interest shown through surveys and discussions. The majority of students have expressed a clear need for learning such problem solving tools during their study NZDE. A large percentage of students have shown self-motivation to learning TRIZ through the online resources offered by the TRIZ Repository. Most of the students assessed self-learning resources offered by the repository of TRIZ educational materials as suiting their learning and their future needs. Their survey responses suggest that the heuristics they have learnt just over a couple of hours have not only helped them in generating more ideas for their projects, but also influenced the way they solve problems.

CONCLUSIONS Introduction of the problem solving techniques such as TRIZ into engineering education has a longstanding need, which is now not just appreciated by the professionals but the students themselves. The feedback from the NZDE study participants indicates the usefulness of the TRIZ heuristics for the NZDE program and especially for the Engineering Project course. It is recommended to introduce thinking heuristics to students early in their engineering study and to develop appropriate summative assessment to evaluate how well they have learnt and used of these heuristics in project work.

KEYWORDS Engineering education, TRIZ, NZDE, creativity, Engineering Project.

Introduction

Institutes of Engineers all over the world have identified problem solving and creativity as vital skills for engineering graduates to possess in the 21st Century (ENAEE, 2015; Engineering Council, 2013; Engineers Australia, 2011; National Academy of Engineering, 2004). Recent reports of Deloitte and the Australian Government specifically mentioned these skills as increasingly important for success of Australian businesses by 2030 (Deloitte, 2017; Department of Emloyment, 2016). Over 800 CEOs of international corporations that were interviewed by IBM supported the importance of creativity in achieving company goals. They suggested that in order to survive and prosper in the world of disruption companies need to accelerate innovation (IBM Institute for Business Value, 2016).

Research evidence on the ability of engineering programs to nurture creative graduates is inconclusive. Some authors reported on failures of current engineering programs to enhance students' creativity (Daly et al., 2014; Sola, Hoekstra, Fiore, & McCauley, 2017; Steiner et al., 2011). On the other hand, there were reports on successes in enhancing problem solving and creativity skills of engineering students (Belski, Baglin, & Harlim, 2013; Hugh et al., 2007). This study is focused on development of creative problem solving skills in engineering diploma students from New Zealand.

The New Zealand Diploma in Engineering (NZDE) is a two-year full time program. It is often considered as the first step in tertiary engineering education. Institutes of Technology are the main providers of the engineering diplomas in New Zealand. They offer diploma programs in four major engineering fields: civil, mechanical, electrical and electronic. These programs must adhere with the Dublin accord of the International Engineering Alliance (International Engineering Alliance, 2016) as well as with New Zealand National Curriculum for engineering diplomas (New Zealand Board of Engineering Diplomas, 2016). In accordance with the National Curriculum, graduates of the Institutes of Technology are expected to develop competencies allowing them to solve well-defined engineering problems (p.45). This, among other skills, requires proficiency in problem identification and problem analysis (p.46).

Significant percentage of the NZDE graduates continue their study at universities in New Zealand and abroad in order to complete a degree of the Bachelor of Engineering (Washington accord) or the Bachelor of Engineering Technology (Sydney accord). Usually NZDE graduates enrol directly in the second year of a bachelor degree. Most universities offer NZDE graduates cross-credits for up to one and a half years of bachelor studies.

The NZDE curriculum is well compiled and includes sufficient volume of engineering theory and engineering practice. At the same time, it does not explicitly address the enhancement of some soft skills, such as problem solving, problem identification and evaluation, risk management, etc. It is anticipated that these soft skills are gained naturally as a result of two years of study. This does not necessarily happen that way. Indeed, some students are more natural learners and are able to acquire problem-solving skills over two years of the diploma study; other students that require extra teaching support may graduate with underdeveloped soft skills. The latter cohort would be much better of if simple heuristics that they can apply in problem solving were taught to them explicitly. Taking into account the constraints of the existing NZDE curriculum, it would be ideal to embed simple problem-solving heuristics into existing NZDE courses. Also, it would be advantageous to utilise existing educational materials that have already been developed by expert problem solvers and that can be used for free.

This study investigates the suitability of educational materials that are offered by the repository of thinking heuristics (TRIZ Repository) developed by the fellowship team led by Belski (OLT Fellowship, 2016) for embedding into the NZDE curriculum. These educational materials have been provided under the Creative Commons licence and could be used freely by both teachers and students. During semester 1 of 2017 four heuristics that belong to the Theory of Invention Problem Solving (TRIZ) were promoted by the fellowship repository.

Three of these heuristics looked suiting the needs of the diploma students. Therefore it was decided to formally introduce to the students the heuristics of *Size-Time-Cost Operator* that guides problem framing and reframing, *Notion of the Ideal Ultimate Result* (IUR) that helps to 'envisage' the future, and *8 Fields of MATCEMIB* that makes idea generation fun.

Methodology

Sixty students enrolled in various diploma programs at the TOI-OHOMAI Institute of Technology (TOIT) were introduced to three TRIZ heuristics in semester 1 of 2017. Twenty-seven students were in their last year of diploma study. Twenty-three students were in their first year of NZDE. Ten student participants have been studying on a part-time basis. They were with TOIT for over two years. The TOIT diploma students come from diverse backgrounds. The students that participated in this study were a mix of school leavers and mature adults. About 20% of them were international students, who mainly came from India.

It was anticipated that learning TRIZ heuristics would help students to excel in courses that are focused on development of soft skills, like Planning, Time and Engineering Management, Creativity, Control and etc. Furthermore, TRIZ problem-solving heuristics could be very useful in completing the Engineering Project that is carried out in the last semester of the diploma study (in semester 2 of 2017 for the cohort of 27 students). The aim of the Engineering Project course explicitly mentions the problem-solving skills: *"To apply knowledge and problem-solving skills to plan and complete an engineering project relevant to the discipline strand studied…"* (New Zealand Board of Engineering Diplomas, 2016, p. 133).

Final Projects of the 27 graduating students represented TOIT diploma programs from all four major engineering fields and were reasonably complex. The following are some of the project titles that the graduating students were involved in: "Simplifying existing drink dispenser", "Design of a model gantry crane", "Design of a prototype conveyor system", "Design of an automated weighting and data recording system for the fish processing plant", "Sun tracking system for solar power", "Developing a PID controlled system for variable speed drive".

Three class sessions on TRIZ heuristics were conducted in order to engage students in enhancing their thinking skills. In the first session, students enrolled in the last year of study were introduced to TRIZ heuristics of *8 Fields of MATCEMIB* and *Size-Time-Cost Operator*. At the beginning of the class they were asked to suggest as many ideas as they could for the ways and the means of protecting buildings from termites. Then, as recommended by the TRIZ Repository, they watched the *8 Fields of MATCEMIB* video and tried to generate as many ideas as possible for the termite protection. Towards the end of this session students were also briefed on the *Size-Time-Cost Operator* heuristic.

The second session was conducted for the students of mechanical engineering that represented both years of NZDE. This session was devoted to the *Notion of the Ideal Ultimate Result* (IUR). Students watched the IUR video and participated in a discussion on the application of this heuristic in their TOIT projects.

The third session was conducted for the students enrolled in the first year of diploma studies. It introduced students to the heuristics of *8 Fields of MATCEMIB* and *Size-Time-Cost Operator* and was conducted in a similar way to the first session.

At the end of each session it was recommended that students devote an hour or two of their personal study time to look through educational materials, papers and case studies offered by the TRIZ Repository. Students in their final year of study were encouraged to use TRIZ heuristics in preparation for their Engineering Project course. They were given permission to incorporate the pdf solution templates (that are available from the TRIZ Repository) for any heuristic they will use into their final Project Report. All students were asked to consider participation in the *Edisons21 Creativity Challenge* that required a formal submission of a report on the outcomes of usage of the heuristics to the fellowship team (OLT Fellowship, 2016).

At the end of a semester students were asked to participate in a survey and to share their experiences in learning TRIZ heuristics. This web-based survey was built and administered by the team that has been developing the TRIZ Repository. The survey consisted of around 60 questions that covered general information about students, their perceptions on their problem solving abilities, their opinions on the quality of self-educational materials available at the fellowship repository and suitability of these materials for their learning. Twenty-one students completed the survey.

Results

Face-to-face sessions

After watching the video on the *8 Fields of MATCEMIB* heuristic, participants of the first and the third sessions proposed many more ideas for building protection against termites. In essence the number of solution ideas doubled as a result of them watching the video. While discussing individual solution ideas, some students revealed that they excluded some ideas that were similar to that generated after they watched the video from the list of possible solutions they have recorded originally, prior to watching the video. Many of the students said that they were simply uncertain of safety and environmental impact of these solution ideas, so they decided to keep them private.

Student reaction to TRIZ heuristics varied from full support to absence of any interest. Some were very exited and said that they will try applying the heuristics to their own “world saving” inventions; some were simply bored. Students from mechanical and electrical streams were much more engaged in class activities that that of the civil discipline. Mature students were much more interested than recent school leavers and were willing to immediately apply TRIZ heuristics to solve their problems.

Survey results

Quantitative outcomes

Twenty participants of the survey were male; one was female. Seven identified themselves as the first year students, 12 – as the second year students. Two participants did not offer their year of enrolment. Six students were younger than 20 years of age. Eleven were between 20 and 30 years old. Two students were in each of the 31 to 40 and 41 to 50 age brackets.

Students were certain in soundness of their problem-solving skills. Table 1 depicts their responses to the survey questions that were related to their problem-solving abilities.

Table 1: Student opinions on their problem-solving abilities. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	I am very good at problem solving	I am unable to tackle unfamiliar problems	So far, I have resolved every problem I faced	I am certain that I am able to resolve any problem I will face
Mean	4.00	2.70	3.40	3.65
SD	0.649	0.865	1.095	0.875

Survey participants positively evaluated the quality of educational materials offered by the TRIZ Repository. Table 2 presents student opinions on the usefulness of materials in general and on the effectiveness of each of the components: a short Video, a Solution Template, a Web Tool and a Cheat Sheet.

Table 2: Student opinions on the usefulness of educational materials offered by the TRIZ Repository. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	Educational materials for self-learning TRIZ heuristics made it easy for me to learn thinking heuristics	A short Video that explained the way to apply a heuristic was very helpful in learning the heuristic	A Solution Template that guided me in applying a heuristic for the first time was very helpful in learning the heuristic	A Web Tool that guided me in applying a heuristic for the first time was very helpful in learning the heuristic	A Cheat Sheet was very helpful in applying the heuristic
Mean	4.00	4.07	4.07	3.69	4.00
SD	0.365	0.594	0.458	0.751	0.816

Student responses to questions related to the influence of the heuristics on their projects and on their approach to problem solving were also positive and are shown in Table 3.

Table 3: Student opinions on the influence of TRIZ heuristics. All questions used the Likert scale of 5 (1 – strongly disagree; 5 – strongly agree)

	I believe the heuristic(s) I have learnt helped me to understand my problem much more clearly	I believe the heuristic(s) I have learnt helped me to generate more ideas for my project	Learning the heuristics changed a way I resolve problems
Mean	4.00	4.06	3.87
SD	0.365	0.443	0.500

Qualitative outcomes

Survey participants were asked to explain the reasons for some of their answers to the above-mentioned questions and also to suggest how the TRIZ Repository can be improved. The following are some student comments.

Comments related to the question "*I believe the heuristic(s) I have learnt helped me to understand my problem much more clearly*":

> *"It makes you think in different ways you would not usually think." "Because I was able to approach the problem from many different angles". "Well the areas I am lacking or struggling to find ideas has been helped by the heuristic". "It helped narrow the problem down into categories that have viable solutions". "Being able to see problems from more than one angle." "Helped to look at the bigger picture".*

Comments related to the question "*I believe the heuristic(s) I have learnt helped me to generate more ideas for my project*":

> *"Heuristic helped me to generate more ideas for my project ".“I'm very experienced with creative problem solving and lateral thinking, accompanied by industry knowledge. Applying heuristics has reinforced my current methodology and generated few new ideas." "Using the size-time-cost helped me generate realistic ideas even when thinking if money was not an issue. By thinking in such a wide point of view can create ideas that can then be broken down into more feasible goals."*

Comments related to the question "*Learning the heuristics changed a way I resolve problems*":

> *"For the most part I already applied a lot of these subconsciously however I do approach the way I solve problems slightly differently." "Because its totally different to my thinking". "Heuristics give me a distinctive view point towards a problem". "Taking time to analyse the problem and think of things that can be resolved with the given time or resources available, or what issues need to be solved in a different perspective".*

Most of the survey participants were overall happy with the materials offered by the TRIZ Repository and suggested minor improvements. One student explicitly suggested the TRIZ heuristics offered by the Fellowship Repository to be promoted to educators:

> *"Please do some adverticements on websites and mail [information on the TRIZ Repository] to tutors and students as well …"*

Discussion

Student opinions presented in Table 1 indicate that the participants were very confident in their problem-solving abilities. Actually, the Diploma students judged their problem-solving skills to be on the par or even exceeding that of the students enrolled in Engineering Degrees in Australia that were evaluated in the past (Belski et al., 2013; Steiner et al., 2011). Perceptions of own problem-solving abilities of the NZDE students differed the most from that of 325 students enrolled in engineering Bachelor degrees that were surveyed by Steiner et al. (2011). The responses of these two student cohorts to the question "*So far, I have resolved every problem I faced*" exhibited the largest discrepancy. As shown in Table 1, the NZDE students evaluated their past problem solving achievements slightly positively (Mean = 3.4/5). Students enrolled in engineering degrees, on the other hand, were neutral (Mean = 3.0/5). It must be noted that the students surveyed by Steiner *et al.* did not study thinking heuristics. The opinions of the NZDE students came out of the survey that was administered after they have learnt TRIZ heuristics from the TRIZ Repository. They were not surveyed prior to the introduction of the heuristics. Therefore it is impossible to establish whether the simple TRIZ heuristics the NZDE students have learnt made any influence on their problem-solving self-efficacy. Such positive influence of TRIZ heuristics on problem solving self-efficacy is possible and has been reported by Belski *et al.* (2013). The change in problem solving self-efficacy of 93 students as a result of learning TRIZ heuristics in a one-semester subject established by Belski *et al.* was statistically significant. The Mean value of student responses to the statement "*I am certain that I am able to resolve any problem I will face*" changed from 2.82/5 to 3.82/5 (Belski et al., 2013, p. 350). The response of the NZDE students to the same statement after learning the heuristics is presented in Table 1. The Mean was 3.65/5, pretty close to 3.82/5.

Students that participated in this study assessed the educational materials provided by the TRIZ Repository that they used as helpful. As shown in Table 2, they agreed with the usefulness of each component of materials available for each heuristic and 'liked' the Video and the Solution Template the most. This suggests that the educational materials that are available at the TRIZ Repository website can be recommended to students for self-learning.

The data presented in Table 3 as well as student comments indicate that a short encounter with simple TRIZ heuristics not only helped them to generate more ideas for their projects, but also made a positive influence on the way they analyse and solve problems. Interestingly, the heuristic of *8 Fields of MATCEMIB* assisted some students in revealing to others the ideas that they had in mind, but were unwilling to share openly.

As it has already been mentioned, not all students showed enthusiasm to upgrade their thinking skills and to participate in activities focused on learning the TRIZ heuristics. Such behaviour is not unique to the introduction of heuristics. Students are often reluctant to engage in any task that is not formally assessed and could not improve their course performance. It is also possible that some final year students hesitated to use the heuristics. Many of them might have had ideas on conducting their project work already and were unwilling to make changes to the ideas that they have developed prior to learning the heuristics.

It seems that in order to actively engage students in learning thinking heuristics and to help them in utilising the outcomes of problem analysis and idea generation achieved with these heuristics it is necessary to make heuristic application a compulsory part of project proposals, and to formally assess the outcomes of the application of heuristics. It would also make good sense to introduce TRIZ assignments in the first-year engineering subjects. Embedding thinking heuristics into early engineering subjects is likely to help students later on, for example in their final year capstone project. If problem solving heuristics are introduced to students from year one, they will have ample time to familiarise with the thinking heuristics before their project work will commence and may be able to accomplish more during their project work.

Conclusion

It has been found that a short introduction of TRIZ heuristics to students enrolled in NZDE resulted both in tangible and intangible outcomes. Many students reported that as a result of learning TRIZ heuristics they came up with new ideas for their projects. Also, students thought that their problem-solving approach has changed as a result of learning TRIZ heuristics and that they will use these heuristics in the future.

Introduction of TRIZ heuristics did not take much time and effort. Appropriate teaching and self-learning materials were simply downloaded from the TRIZ Repository. Therefore, engineering educators may need to consider utilising the resources offered by the TRIZ Repository in their own courses.

Although the majority of the students that participated in this study were excited to learn thinking heuristics, some students were reluctant to devote their time to the heuristics. In order to ensure that all students consider enhancement of their cognitive skills seriously and devoting appropriate time to studying thinking heuristics it is recommended that the heuristics are introduced to students early in their engineering study. They need to be given adequate time to familiarise with the thinking heuristics in order to effectively use these heurists in their project work.

References

Belski, I., Baglin, J., & Harlim, J. (2013). Teaching TRIZ at University: a Longitudinal Study. *International Journal of Engineering Education, 29*(2), 346-354.

Daly, S. R., Mosyjowski, E. A., & Seifert, C. M. (2014). Teaching Creativity in Engineering Courses. *Journal of Engineering Education, 103*(3), 417-449. doi:10.1002/jee.20048

Deloitte. (2017). *Soft skills for business success* (MCBD_USICS_05/17_054338). Retrieved on the 21th of June 2017 from: https://www2.deloitte.com/au/en/pages/economics/articles/soft-skills-business-success.html

Department of Emloyment. (2016). *Employability Skills Training: Consultation Paper*: Australian Governmnet.

ENAEE. (2015). EUR-ACE® Framework Standards And Guidelines (pp. 23). EU: ENAEE.

Engineering Council. (2013). UK Standard for Professional Engineering Competence (pp. 48). UK: Engineering Council.

Engineers Australia. (2011). *Stage 1 Competency Standard For Professional Engineer*. Retrieved from Retrieved on the 16th of January 2013 from: https://www.engineersaustralia.org.au/about-us/program-accreditation - standards

Hugh, A. B., Alan, L. G., Ira, G., Satyandra, K. G., Lawrence, S. G., Jr., Edward, B. M., & Brent, W. S. (2007). Training mechanical engineering students to utilize biological inspiration during product development. *Bioinspiration & Biomimetics, 2*(4), S198.

IBM Institute for Business Value. (2016). *Redefining Competition: Insights from the Global C-suite Study – The CEO perspective*. Retrieved on the 21th of June 2017 from: https://public.dhe.ibm.com/common/ssi/ecm/gb/en/gbe03719usen/GBE03719USEN.PDF

International Engineering Alliance. (2016). *International Engineering Alliance: Educational Accords*. Retrieved on the 21th of June 2017 from: http://www.ieagreements.org/assets/Uploads/Documents/Policy/IEA Rules and Procedures (3 June 2016).pdf

National Academy of Engineering. (2004). *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press.

New Zealand Board of Engineering Diplomas. (2016). New Zealand Diploma in Engineering. National Curriculum Document. (pp. 227). NZ: New Zealand Board of Engineering Diplomas.

OLT Fellowship. (2016). TRIZ Repository. Retrieved on the 21th of June 2017 from: http://www.edisons21.com

Sola, E., Hoekstra, R., Fiore, S., & McCauley, P. (2017). An Investigation of the State of Creativity and Critical Thinking in Engineering Undergraduates. *Creative Education, 8*(09), 1495.

Steiner, T., Belski, I., Harlim, J., Baglin, J., Ferguson, R., & Molyneaux, T. (2011). Do we succeed in developing problem-solving skills–the engineering students' perspective. In Y. M. Al-Abdeli & E. Lindsay (Eds.), *The 22nd Annual Conference for the Australasian Association for Engineering Education* (pp. 389-395). Fremantle – Western Australia: Engineers Australia.