Can One Class Hour Improve Creative Problem Solving Self-efficacy

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STRUCTURED ABSTRACT

CONTEXT
Development of engineers ready to work in the 21st Century requires engineering educators to revisit a set of skills that need development and to rethink learning outcomes to be achieved. Governments, business leaders and professional associations believe that enterprise skills, which include: digital literacy, interaction and creative problem solving skills are those most needed by university graduates in the 21st Century. This paper is devoted to the development of creative problem solving skills.

PURPOSE
To establish whether introducing students to simple thinking heuristics in class can change and improve their creative problem solving self-efficacy.

APPROACH
Over 700 students were enrolled in a first-semester, first-year subject related to the Engineers Without Borders (EWB) Challenge in which students work in groups to develop a solution to opportunities in a developing country. Tutors introduced students to thinking heuristics at an early stage (week 2) of the course for idea generation and midway through the course (week 7) to enhance technical content of their developing solutions. Approximately one hour of class time was devoted to exploring the understanding of these thinking tools. This varied to some degree between classes and included showing a 15 minute video introduction, including summaries of selected heuristics in tutorial activities and recommending students study more thinking heuristics from the TRIZ Repository (Edisons21.com). In order to establish changes in creative problem solving self-efficacy, students were surveyed at the beginning and the end of the semester.

RESULTS
The outcomes of the surveys are analysed. It was found that students’ creative problem solving self-efficacy changed significantly during the progress of the course on some of the survey metrics applied. A component of this improvement is anticipated to be as a result of learning simple thinking heuristics.

CONCLUSIONS
It seems that devoting one hour of a face-to-face class to introduce an effective thinking heuristics can positively influence students’ creative problem solving self-efficacy. In turn, improvement in creative problem solving self-efficacy is likely to make students more effective in generating appropriate solution ideas. Therefore, engineering educators need to consider embedding effective thinking heuristics into their existing discipline-based subjects.

KEYWORDS
Creative problem solving, self-efficacy, idea generation, thinking heuristics.
Introduction

Importance of creativity skills

The need for sound creativity and problem solving skills has been declared by Institutes of Engineers all over the world. Nevertheless, a number of scholars have reported on failures of current engineering programs to enhance students’ creativity (Daly, Mosyjowski, & Seifert, 2014; Sola, Hoekstra, Fiore, & McCaulley, 2017; Steiner et al., 2011; Valentine, Belski, & Hamilton, 2018). For example, Steiner et al. (2011) surveyed engineering students of all year levels that were enrolled in variety of programs at an Australian Technology Network (ATN) university and discovered that problem solving self-efficacy dropped over the four years of an engineering degree. Findings on the ‘detrimental’ role of the years of studying engineering on creativity skills of students have been reported by Valentine, Belski, & Hamilton (2018). They involved 26 first-year, 34 third year, and 27 postgraduate students in an idea generation experiment and discovered that the first-year students generated statistically significantly more ideas than their older counterparts. Also, the third year students statistically significantly outperformed their postgraduate colleagues in the number and the breadth of the ideas proposed to an open-ended problem.

Decline in creativity skills during engineering study years is not surprising. Recent findings of Valentine, Belski, and Hamilton (2017) revealed a lack of focus on creative problem solving in Australian engineering curricula. Valentine et al. reviewed all Australia-based electrical engineering single degrees accredited by Engineers Australia that were offered during the first half of 2017 and provided program handbooks on the Web. Overall, 34 study programs at 25 Australian universities comprising 919 core courses were considered. It was found that only 20 course outlines at 17 institutions explicitly specified that some concepts of creativity and/or innovation relevant to engineering are demonstrated or explained to students. Not one program included core courses that explicitly exposed students to, or required application of, creativity heuristics or techniques. Very few courses mentioned the need for students to demonstrate creativity and innovation (Valentine et al., 2017).

Educating creative engineers represents a permanent challenge for engineering education in many countries. Daly et al. (2014), who examined the learning outcomes of engineering courses at a number of universities in the United States of America (USA), found that these courses adequately addressed the development of convergent thinking skills but did not contain much instruction on creativity skills. Gaudron and Kövesi (2017) recently analysed opinions of French engineering students on the skills they would need to possess to innovate as well as students’ perceptions on gaining these skills while studying engineering. The biggest disagreement between the importance of the skill and the successful acquisition of that skill at university was discovered for the creativity skill (4.2 versus 1.7; on the Likert scale of 5, with 1 corresponding to complete disagreement and 5 – to complete agreement) (Gaudron & Kövesi, 2017).

This paper presents the outcomes of a study devoted to enhancement of creativity skills of engineering students by means of engaging them in learning simple creativity heuristics during a one-hour tutorial.

Definition of creativity in engineering

Recent research findings imply that creativity is domain-specific (Baer, 2015). Creativity scholars established that a person who is creative in one domain is not necessarily creative in another domain (Baer, 2012; Weisberg, 2006). Also creativity training only enhances creativity skills in the domain of the training and does not transfer to other domains of human activity (Baer, 2016; Scott, Leritz, & Mumford, 2004).

In light of domain specificity of creativity skills, this paper accepts the definition of engineering creativity based on analysis of legal aspects of patentability and patent authorship (Belski, 2017):

“Engineering creativity is the ability to generate novel solution ideas for open-ended problems, ideas that are not obvious to experts in a particular engineering discipline and that are considered by them as potentially useful”. (Belski, 2017, p. 327)

Based on this definition, the authors have chosen the heuristics that belong to the Theory of Inventive Problem Solving (TRIZ) to be introduced to the students involved in this study.
TRIZ heuristics chosen

TRIZ is a generic name for a family of heuristics (methods) for problem analysis, reframing, failure analysis and idea generation. TRIZ originated from the analysis of thousands of patents that revealed objective trends of development of technical systems (Altshuller, 1984). TRIZ heuristics are well structured and help engineering professionals in systematic utilisation of their knowledge. Hu, Shealy, & Gero (2018) recently reported that TRIZ is likely to instil more creative thinking than other design thinking methods. They investigated changes in brain activity of 12 students that were involved in designing of three artefacts. Students used TRIZ, Brainstorming and Morphological Analysis. Hu, Shealy, & Gero (2018) reported that

“...with more inter-hemisphere and intra-hemisphere connectivity during concept generation using TRIZ, engineering students were possibly most capable of using divergent ways of thinking to enhance creativity during design.” (Hu et al., 2018, p. 9)

TRIZ heuristics of Resources and Eight Fields of MATCEMIB (Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological) were chosen for the current experiment. The former engage a user in deliberate consideration of Resources including Substance, Energy, Information, Time, Space, Function, System that may contribute to a solution (OLT Fellowship, 2016). The Resources heuristic engages users in establishing the resources that are available to them. This helps them to achieve their design/problem solving goals with less effort and in minimal time. The heuristic of Eight Fields of MATCEMIB guides a practitioner in the 'manual' search of her/his knowledge database (Belski, 2007). It has been reported that this heuristic was very helpful in boosting the number of ideas generated by students for an open-ended problem (Belski et al., 2015).

Methodology

Course

At RMIT University the term ‘course’ is used to describe an individual unit or subject of study. Introduction to Professional Engineering Practice is a core course common to the first-semester of most engineering programs at RMIT University. 2018 was the first-year in which it was run as a single common course rather than as similar parallel courses in separate engineering discipline areas. This resulted in a cohort of over 700 students in the course. The course is taught in a face-to-face mode with students split into three streams of lectures and 29 weekly tutorial classes. The tutors included experienced full-time academic staff (4), post-doctoral fellows (3), post-graduate students (9) and senior undergraduate students (2). The subject coordinator and a co-author of this paper were each responsible for two tutorial classes. Tutors facilitate the students’ group work on a weekly basis.

Learning Activity

For over a decade, foundational engineering courses at RMIT University have used The Engineers Without Borders (EWB) Challenge as the context in which to introduce students to the concept of professional engineering practice. With student projects focussed on real world humanitarian engineering opportunities The EWB Challenge allows students to learn communication, project management, ethics, decision making, working in teams, risk assessment and design whilst participating in a national competition.

Each year, since the first EWB Challenge in 2007, Engineers Without Borders has partnered with a different non-government organisation to identify a community or communities that may benefit from participating in the EWB Challenge. Through EWB facilitated Human Centred approaches community members identify opportunities and aspirations for their own community which the EWB team translate into a suite of engineering design areas. These design areas often cover themes such as water supply, sanitation, waste management and ICT. A context specific briefing and supporting resources are provided to students by EWB whose universities have subscribed to The EWB Challenge. According to Smith et al. (2017) each year in Australasia over 9,000 students work in teams to develop innovative solutions to one of the design areas identified in the briefing documentation.

There is a competitive element to the EWB Challenge; the best projects from each participating university are assessed by industry experts with the top scoring ideas from each Australian state and New Zealand being invited to a national showcase. These best project ideas are 'pitched' back to members of the community who devised the EWB Challenge design areas in the first place.
There are many educational benefits for students participating in the EWB Challenge. Jolly, Crosthwaite, & Kavanagh (2010) note that “One of the ways in which subjects containing the EWB Challenge are different from others is in their emphasis on teamwork, communication, social and cultural responsibility and liaising with external experts such as EWB staff and industry representatives”. For many first-year students this is an opportunity to learn about the role of the professional engineer in society. Much of professional engineering is conducted in teams and real world projects making the EWB Challenge particularly well suited for teaching students about team work and team roles (Stappenbelt & Rowles, 2009). The design areas covered are all linked to sustainable development practices; as noted in the UNESCO global report on engineering (2010) it is the generation of engineers currently passing through university who must be adequately prepared to “address the global challenges of poverty, sustainability and equality in innovative ways”. Whilst, for this reason, initially participating in the EWB Challenge may seem intimidating there is a novel factor, that essentially from day one of their university careers, students are working on a real world project.

Introduction of Creative Thinking Heuristics

Creative thinking heuristics were presented to students in the early stages of their project work. The heuristics were obtained from the TRIZ Repository (OLT Fellowship, 2016). One page summaries of two creative thinking heuristics were provided on the learning management system for the subject.

Tutors were asked to show students how to apply these techniques in the development of their projects. The tutors were free to explain these techniques according to the needs of their course including the use of videos and supporting presentation material.

Student and Staff Surveys

Three surveys were prepared in Qualtrix: 1) an initial survey of students self-reporting of creative thinking skills, 2) a follow-up survey of students self-reporting of creative thinking skills after completing the EWB project and 3) a survey of tutors about what methods they used to outline the creative thinking techniques. The questions were developed by the authors to assess the role of the TRIZ heuristics in the course and to enquire into creative thinking in the Engineers Without Borders Challenge project more generally. Student surveys were administered in the first and the last week of semester. Tutors were surveyed two weeks after the end of semester. The surveys included questions with five-point Likert scale responses with low numbers representing agreement and high numbers representing disagreement. Some open-ended questions were also included in the surveys but the responses are not reported in this paper. All survey responses were anonymous. The Surveys 1 and 2 will be compared to identify whether students self-report changes to their creative thinking ability as a result of being exposed to the creative thinking techniques and experiencing a creative team project. Survey 3 will be reviewed to recognise the differences in approach to promoting the creative thinking techniques across the cohort. Due to the anonymous nature of the surveys it will not be possible to directly correlate specific responses between the three surveys. Interpretations will be made from each of the surveys separately with some inferences derived from comparison of the three surveys.

Results

Surveys of Students

The response to the initial (before) survey was good with 216 students returning the survey. The follow-up (after) survey at the end of semester also received a good response with a total of 129 surveys being returned. The end of semester survey included a question “This semester I have learnt the idea generation technique of ‘Eight Fields of MATCEMIB’”. A substantial number of students (54, 42%) answered ‘yes’ to this question. However, an even greater number of students (75, 58%) answered ‘no’ to this question. In contrast, the tutor survey showed all responding tutors had presented the ‘Eight Fields of MATCEMIB’ in their classes. Possible reasons for this division of responses will be considered in the Discussion. These two groups (yes = TRIZ-yes, no = TRIZ-no) provided an opportunity to investigate whether answers to other questions had significant differences between these two groups.

A summary of the data from seven self-assessment questions in the before and after surveys is provided in Table 1. Responses to the survey administered at the beginning of the semester are shown as group pre-TRIZ (beginning of semester); survey responses to the second (after) survey are
shown as groups TRIZ-yes and TRIZ-no. The group TRIZ-yes unites the students that indicated that they have learnt the heuristic of the Eight Fields of MATCEMIB; students from the TRIZ-no group believed that they did not learn this heuristic. Table 1 provides the information on the group sizes (N), as well as on the mean (Mean) values and standard deviations (SD) of the mean for each group for each of the seven questions.

SPSS was used to evaluate statistical differences in student answers to survey questions. The Shapiro-Wilk test showed that the distributions of student responses to all questions were not normal. Therefore, the Mann Whitney U test was used to compare perceptions of students from groups TRIZ-yes, TRIZ-no and pre-TRIZ. The **Bolded** Mean values in Table 1 correspond to statistical significant difference of perceptions of students from groups TRIZ-yes and TRIZ-no compared with group pre-TRIZ. The **Bolded and Italicised** Mean value identifies statistical significant difference in perception of students from group TRIZ-yes compared with groups TRIZ-no and pre-TRIZ. For five questions the TRIZ-yes response had a statistically significant difference to responses to both the pre-TRIZ survey and the TRIZ-no group. For one question the TRIZ-yes response had a statistically significant difference to responses to the pre-TRIZ survey only. For two questions the TRIZ-no response had a statistically significant difference to responses to the pre-TRIZ survey.

**Table 1: Data from survey of students**

<table>
<thead>
<tr>
<th>Question</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am good at coming up with new ideas</td>
<td>TRIZ-yes</td>
<td>54</td>
<td>1.87</td>
<td>0.551</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>75</td>
<td>2.16</td>
<td>0.754</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>216</td>
<td>2.16</td>
<td>0.612</td>
</tr>
<tr>
<td>I have a lot of good ideas</td>
<td>TRIZ-yes</td>
<td>54</td>
<td>2.15</td>
<td>0.711</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>75</td>
<td>2.32</td>
<td>0.774</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>216</td>
<td>2.34</td>
<td>0.597</td>
</tr>
<tr>
<td>I have a good imagination</td>
<td>TRIZ-yes</td>
<td>54</td>
<td>1.81</td>
<td>0.729</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>74</td>
<td>2.03</td>
<td>0.827</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>214</td>
<td>2.01</td>
<td>0.722</td>
</tr>
<tr>
<td>I am very good at problem solving</td>
<td>TRIZ-yes</td>
<td>54</td>
<td>1.80</td>
<td>0.562</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>75</td>
<td>1.99</td>
<td>0.647</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>215</td>
<td>1.98</td>
<td>0.652</td>
</tr>
<tr>
<td>I am unable to tackle unfamiliar problems</td>
<td>TRIZ-yes</td>
<td>53</td>
<td>3.38</td>
<td>1.004</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>75</td>
<td>3.35</td>
<td>0.937</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>216</td>
<td>3.34</td>
<td>0.869</td>
</tr>
<tr>
<td>So far, I have resolved every problem I faced</td>
<td>TRIZ-yes</td>
<td>53</td>
<td>2.57</td>
<td>1.065</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>75</td>
<td>2.59</td>
<td>0.931</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>216</td>
<td>2.92</td>
<td>0.888</td>
</tr>
<tr>
<td>I am certain that I am able to resolve any problem I will face</td>
<td>TRIZ-yes</td>
<td>54</td>
<td>2.35</td>
<td>1.012</td>
</tr>
<tr>
<td></td>
<td>TRIZ-no</td>
<td>74</td>
<td>2.45</td>
<td>0.981</td>
</tr>
<tr>
<td></td>
<td>Pre-TRIZ</td>
<td>215</td>
<td>2.62</td>
<td>0.811</td>
</tr>
</tbody>
</table>

**Survey of Tutors**

Response rate to the tutor survey was low, which is attributed to the conclusion of the semester of teaching and the moving on of tutors to new activities. Nine of the 18 tutors responded to a survey about creative thinking in the course. It became clear from the survey of tutors that the learning experience in each class was different.
Discussion

Groupings TRIZ-yes and TRIZ-no

It was a surprising finding that the majority of students (58%, designated group TRIZ-no) reported not having learnt one of the creative thinking heuristics. It is possible that some tutors did not present detailed information about the technique or its use despite instructions from the course coordinator. It is also possible that by the end of the semester many students had forgotten being introduced to the technique. It is not possible to resolve the reason for the high number of students reporting that they did not learn the technique. However, it has provided insight into the self-reporting of creative thinking attributes in other survey questions as will be discussed below.

Statistically Significant Observations

The seven questions in the student surveys and the statistically significant observations are summarised in Table 1. Question 1 provided the greatest contrast between the group who recalled being taught one of the heuristic techniques and both the initial survey and the other group within the after survey. Responses to this question justify the conclusion that students who recalled learning creative thinking heuristics had significantly higher idea generation self-efficacy than students who believed that they did not learn creative thinking heuristics.

As shown in Table 1, students from the TRIZ-yes group changed their views on their idea generation and problem solving abilities (Questions 2 to 4) statistically significantly as a result of the course. At the same time, the perceptions of students from the TRIZ-no group are practically the same as they were at the beginning of the semester. The fact that students from the TRIZ-yes group statistically significantly changed their perceptions on Questions 2 to 4 compared to their colleagues from the pre-TRIZ group and that the perceptions of students from the TRIZ-no group are identical to that of the pre-TRIZ group, suggest that the absence of statistical significance between perceptions of students from groups TRIZ-yes and TRIZ-no on Questions 2 to 4 is likely to be due to insufficient number of survey respondents to the survey at the end of semester. In other words, it can be concluded that one hour tutorial on the Eight Fields of MATCEMIB heuristic significantly changed student opinions on their idea generation and problem solving abilities (Q1 to Q4).

Question 5 was the only question framed in a negative sense. The responses were clearly dominantly located in disagreement (higher scores) than all other questions which suggests that respondents were reading questions sufficiently carefully to note the change in sense from positive to negative. No further interpretations can be drawn from responses to this question.

Question 6 and 7 were framed as behavioural rather than attitudinal. Both groups TRIZ-yes and TRIZ-no were in higher agreement with the statements than in the initial survey. In both questions TRIZ-yes showed slightly greater agreement but not significantly so. It is interesting that most students have expressed increased self-confident in their success at problem solving in the past (Q6) and future (Q7). It is possible that in the initial survey (pre-TRIZ) some students may have lacked a context in which to apply these behavioural questions. It is possible that at the conclusion of the Engineers Without Borders Challenge project, the students had a context for applying the questions. The observation that self-efficacy in these areas increased may have been simply because of the contextual clarity. It is possible that the responses indicate that students gained self-efficacy in their problem solving skill by completing the project, but the data cannot be used to test this interpretation.

Conclusions

The results of this study support the findings of two other studies that reported on the influence of thinking heuristics from the TRIZ Repository on students’ problem-solving abilities (Blicblau & Ang, 2017; Shukhmin & Belski, 2017). Participants of this study who recalled learning creative thinking heuristics had significantly improved their idea generation and problem-solving self-efficacy. This improvement happened as a result of exposure to these heuristics for just one tutorial hour.

These findings support the benefits of thinking heuristics. The findings also support the proposal that degree to which students are able to recall the creative thinking heuristics is a significant determinant on students’ self-reported creativity. The survey of tutors showed that the in-class experience varied significantly in each class. Ensuring that student are taught such methods in a consistent manner with appropriate reinforcement is expected to further enhance students ability to apply creative thinking in their engineering studies.
References


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