ATAR, Prior Knowledge and Performance in Idea Generation

Gavin Buskes[1]; Iouri Belski[2]
[1] The University of Melbourne, [2] Royal Melbourne Institute of Technology
Corresponding Author Email: *g.buskes@unimelb.edu.au*

STRUCTURED ABSTRACT

CONTEXT
Buskes and Belski (2017) carried on a discussion that was initiated by Belski and Belski (2016) on the entry prerequisites of engineering programs in Australia. By reflecting on the poor idea generation performance of undergraduate engineering students from one of the Australian Technology Network (ATN) universities with that of engineering students from Czech Republic, Finland and Russian Federation, who participated in an identical idea generation experiment, Belski and Belski (2016) advocated the need to make engineering entry requirements for science knowledge more stringent. After conducting the same experiment with students from one of the Australian Group of Eight (Go8) universities Buskes and Belski (2017) established that the breadth and the number of the ideas proposed by students from the Go8 university Control group moderately and statistically significantly correlated with the number of science subjects students completed at secondary school.

PURPOSE
This paper presents the outcomes of an additional run of the same idea generation experiment that was again conducted at the same Go8 university. The authors planned to establish whether students' performance in idea generation depended on their Australian Tertiary Admission Rank (ATAR).

APPROACH
Six hundred and five students, who have just enrolled in an engineering systems subject at the same Go8 university participated in an identical experiment to that conducted by Buskes and Belski (2017). Students were asked to provide their ATAR scores in order to evaluate its influence on their idea generation. Student solution ideas were assessed by three independent judges that used the same evaluation criteria as the earlier study.

RESULTS
Out of 605 students that participated in the experiment, 313 provided their ATAR score. It was discovered that the ATAR scores did not correlate with the number and the breadth of ideas proposed by the students.

CONCLUSIONS
It seems that the ATAR score on its own is not an adequate criterion for idea generation performance, with prior knowledge in science being found to be a superior estimator. Entry requirements into engineering programs, where idea generation performance is increasingly seen as an essential skill for an engineer to possess, could therefore be adapted to reflect this observation and provide less focus on ATAR score and more on prior science knowledge.

KEYWORDS
Prior knowledge, science knowledge, idea generation.

Introduction

The Foundation for Young Australians (FYA) recently released the outcomes of an analysis of 4.2 million job advertisements that were published in Australia from 2012 to 2015. The FYA discovered a sharp increase in the number of advertisements that expect candidates to possess high-level enterprise skills. Enterprise skills are defined by the FYA as 'generic', combining three groups of skills: skills of digital literacy, creative problem-solving skills and interaction skills. The FYA reported that in the four year period demand for interaction skills grew by 71%; for digital literacy by 212% and for creative problem solving by 249% (Foundation for Young Australians, 2016).

The importance of creativity has been highlighted by Engineers Australia through identifying creativity as a required skill for engineering graduates of the 21st century (Engineers Australia, 2011); by the Australian Department of Employment, that mentioned the skill amongst 10 Core Skills for Work in the 21st century (Department of Employment, 2016) and also by Deloitte that reported the importance of creativity for the success of Australian businesses by 2030 (Deloitte, 2017).

It needs to be noted that numerous scholars have postulated that engineering creativity is closely related with the ability to generate novel ideas and suggest that to enhance students' creativity it is required to boost their divergent thinking skills (e.g. Belski, 2017; Daly, Mosyjowski, & Seifert, 2014).

As a result of comparing the performance of undergraduate engineering students from four countries in the same idea generation experiment, Belski and Belski (2016) surmised that Australian engineering graduates might be lagging their counterparts from other countries in their creativity skills. In that experiment, students enrolled in engineering degrees at one of the Australian Technology Network (ATN) universities performed statistically significantly below their international counterparts from universities of technology in Czech Republic, Finland and Russian Federation in terms of both the number and breadth of ideas generated for the same open-ended problem (Belski et al., 2015). To establish the reasons that could have contributed to the significantly lower performance of Australian students, Belski and Belski (2016) considered the following seven factors: *"(a) differences in prior science knowledge of the student participants, (b) differences in their experiences, (c) dissimilarity in their creativity skills, (d) differences in student motivation during idea generation, (e) differences in experimental conditions, (f) cultural and language differences as well as (g) the influence in the treatment that the experimental groups were under"* (Belski & Belski, 2016, p. 2).They concluded that the main reason for such poor performance of Australian students was due to their insufficient knowledge of science that, in turn, was a result of low prerequisites on science knowledge for entering their engineering degree. Based on that conclusion, Belski and Belski (2016) advocated the need to make engineering entry requirements for science knowledge more stringent.

Buskes and Belski (2017) carried on the discussion initiated by Belski and Belski (2016) on the entry prerequisites of engineering programs in Australia. By conducting the same experiment with 93 students that have just enrolled in the Bachelor of Science degree at one of the Australian Group of Eight (Go8) universities, Buskes and Belski (2017) established that the performance of students from a Go8 institution was on par with that of students from Czech Republic, Finland and the Russian Federation. They also established that the breadth and the number of independent solution ideas proposed by students from the Go8 Control group moderately and statistically significantly correlated with the number of science subjects that students completed at secondary school. Buskes and Belski (2017) argued that the absence of similar correlation in the three experimental groups were likely to be due to the experimental treatment (the words that were shown to students every two minutes) and suggested that other factors, like the Australian Tertiary Admission Rank (ATAR) might have played a significant role in the outcomes of idea generation at Australian universities. The ATAR score ranges between 0 and 99.95 and designates a student's position relative to all of the students who graduated from secondary school in the same year. A student with ATAR of 98.95, for example, is considered as performing better than 98.95% of all secondary school graduates of the same year. Buskes and Belski (2017) also noticed that the words that were shown to students from the experimental groups without explanation could have puzzled students from an international background.

This paper presents the findings of a study that tried to look at the influence of ATAR on idea generation performance and also to compare performance of international and local students enrolled in the first year of a common science program.

The following are the two hypotheses that were investigated in this study:

1. Hypothesis 1: The ATAR score is positively correlated with the number and the breadth of ideas generated by students.

2. Hypothesis 2: Local and international students enrolled in the first year of the common science program at a Go8 university that belonged to the same experimental group are indistinguishable in the number and breadth of the ideas generated by them for the open-ended problem.

Methodology

Six hundred and five students that have just enrolled in the Bachelor of Science degree at the same Go8 university participated in this study. Sixty-eight percent of the participants graduated from secondary school in Australia; 32% were international school graduates.

This study repeated the idea generation experiment that was originally conducted by Belski et al. (Belski, Hourani, Valentine, & Belski, 2014). Students from numerous tutorial groups were randomly assigned to four conditions: one control and three experimental. All participants were given 16 minutes of tutorial time to individually generate as many ideas as possible for the same open-ended problem (to remove the lime build-up in water pipes). Prior to generating ideas, tutors presented students with the same PowerPoint slide for two minutes. This slide contained the problem statement and a photo of a cross-section of a pipe, half of which was covered with lime deposit. This slide is shown in Figure 1a. After a two-minute introduction to the problem that covered only the information presented in Figure 1a, all students were asked to work individually and to record as many ideas as possible to remove the lime build-up from the pipes. The form to record ideas was distributed to the students just before the problem was presented. The form was the same for the students of all four groups and was the same form that was used in the original experiment but with some extra fields for students to indicate whether they studied physics, chemistry, biology, mathematical methods and specialist mathematics at secondary school.

Students from the Control group were not influenced by any ideation methodology. After two minutes of problem introduction, they were allowed to think of solution ideas and to record them for 16 minutes. The slide shown in Figure 1a was presented to the students from the Control group for the whole duration of the idea generation session.

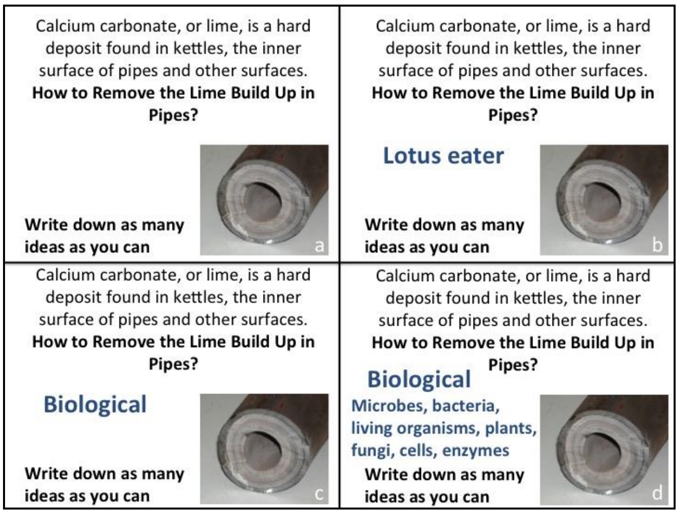

Figure 1: The Power Point slides presented to students: a) task introduction and Control group; b) Random Word group; c) MATCEMIB group; d) MATCEMIB+ group (Belski et al., 2015).

After two minutes of problem presentation, students from the three experimental groups were told that during their idea generation session some additional words will be shown on the PowerPoint slide. No explanation of what these words will be and what to do with them were given. Students from the Random Word groups were offered the eight random words that were used in the original experiment (i.e. Archaism, Right angle, Lotus eater, Emitter, Ozone, Blowhole, Ball-and-socket-joint and Hanky-panky). Students from the MATCEMIB group were shown the names of the eight fields of MATCEMIB (i.e. Mechanical, Acoustic, Thermal, Chemical, Electric, Magnetic, Intermolecular and Biological). The MATCEMIB+ group students were presented with the names of the eight fields (in large font) as well as some words (in small font) that illustrated the interactions of the particular field (e.g. for the Mechanical field - friction, direct contact, collision, wind, etc.) The name of each field as well as each random word was shown to the students from the experimental groups for two minutes. Every two minutes a tutor changed the word on the screen and read the new word aloud. When a tutor of the MATCEMIB+ group changed slides every two minutes, they read aloud only the name of the field of MATCEMIB that was displayed in large font, but did not read the words that illustrated field interactions that were displayed in small font together with the field's name. Altogether the students from all groups were generating and recording ideas for 16 minutes. Figure 1 depicts one of the eight PowerPoint slides that were shown to students from different groups: Figure 1a – Control group; Figure 1b – Random Word group; Figure 1c – MATCEMIB group; Figure 1d – MATCEMIB+ group.

Three independent assessors were trained to evaluate the student idea generation forms using the criteria that were developed for the original idea generation experiment (Belski et al., 2014). In order to do that, assessors watched a video that explained the assessment criteria and showed the evaluation of ideas proposed by three students. They also evaluated performance of eight students as an assessment exercise. The inter-rater reliability of their assessment was evaluated with SPSS by establishing the Cronbach's Alpha for the number of independent ideas proposed by each individual student. The Cronbach's Alpha exceeded 0.9, which suggested excellent internal consistency of assessment of the three assessors. After that, the assessors evaluated all student idea generation forms. Among other items, assessors counted the number of distinct (independent) ideas proposed by each student without necessarily assessing their practicality. In order to judge how broad these independent ideas were, each idea was assigned to a field of MATCEMIB that most closely matched the proposed principle of operation. The assessors have also been asked to assign the ideas of each student a perceived 'Creativity' level (from 0, that corresponded to absence of creativity to 10, identifying a superior creativity level of solution ideas).

Results

Table 1 presents the results for the average number of independent ideas proposed by the students in each group (Mean) and the breadth of these ideas (Breadth). It also contains information on the group size (N) and Standard Deviations (SD) of the Mean and the Breadth.

Table 1: Number (Mean) and Breadth of distinct ideas generated by students

Group	N	Mean	SD	Breadth	SD
Control	157	3.09	2.01	2.34	1.04
Random W	164	3.79	2.34	2.62	1.20
MATCEMIB	116	5.67	2.45	4.15	1.57
MATCEMIB+	168	5.70	2.77	4.10	1.53

SPSS was used for statistical analysis of all results. The Shapiro-Wilk test identified that the distributions of the number of ideas and the breadth of ideas shown in Table 1 were not normal for all four groups. Therefore, the Kruskal–Wallis test was used to evaluate differences in performance of students from the four groups, revealing a statistically significant difference in both the number and breadth of ideas between the groups ($p<0.001$). Post hoc pairwise comparisons (Dunn-Bonferroni) showed statistically significant differences in the numbers of ideas generated by students from the Control group and the MATCEMIB group ($Z=-8.79$, $p=0.000$) as well as the Control group and the MATCEMIB+ group ($Z=-9.42$, $p=0.000$). Students from the Random Word group were outperformed by students from the other two experimental groups in the number of the ideas proposed: the MATCEMIB ($Z=-6.39$, $p=0.000$) and the MATCEMIB+ group ($Z=-6.78$, $p=0.000$). Differences in the number of ideas generated by students from all other groups were not statistically significantly different.

Similarly, the Kruskal–Wallis test showed statistically significant differences in the breadth of ideas generated by students from the Control group and the MATCEMIB group ($Z=-9.35$, $p=0.000$) as well as the Control group and the MATCEMIB+ group ($Z=-10.25$, $p=0.000$). Students from the Random Word group suggested statistically significantly less breadth of ideas than students from the other two experimental groups: the MATCEMIB ($Z=-7.95$, $p=0.000$) and the MATCEMIB+ group ($Z=-8.73$, $p=0.000$). Differences in the breadth of ideas generated by students from all other groups were not statistically significantly different.

Table 2 depicts the outcomes of idea generation for all 313 student-participants that provided their ATAR scores. In addition to the number and breadth of independent ideas proposed by the students, Table 2 offers information on the average 'Creativity' level of each group (out of 10).

Table 2: Number (Mean), Breadth of ideas, Creativity and ATAR

Group	N	ATAR	SD	Mean	SD	Breadth	SD	Creativity	SD
Control	89	92.6	5.0	3.03	1.82	2.36	1.01	3.81	1.93
Random W	79	92.5	4.9	3.94	2.33	2.63	1.15	4.78	2.24
MATCEMIB	76	91.9	5.2	6.00	2.49	4.26	1.54	6.30	1.95
MATCEMIB+	69	91.7	6.6	5.68	2.81	3.99	1.49	5.71	2.20

As shown in Table 2, the average ATAR scores of students from all four groups were very similar. Shapiro-Wilk test identified that the distributions of the number of ideas, the breadth of ideas and creativity level shown in Table 2 were not normal for all four groups. Therefore, the Kruskal–Wallis test was used to evaluate differences in performance of students from the four groups. The Kruskal–Wallis test showed statistically significant differences in the numbers of ideas generated by students from the Control group and the MATCEMIB group (Z=-7.66, p=0.000) as well as the Control group and the MATCEMIB+ group (Z=-6.55, p=0.000). Students from the Random Word group were outperformed by students from the other two experimental groups in the number of the ideas proposed: the MATCEMIB (Z=-5.10, p=0.000) and the MATCEMIB+ group (Z=-4.09, p=0.000). Differences in the number of ideas generated by students from all other groups were not statistically significantly different.

Similarly, the Kruskal–Wallis test also showed statistically significant differences in the breadth of ideas generated by students from the Control group and the MATCEMIB group (Z=-7.74, p=0.000) as well as the Control group and MATCEMIB+ group (Z=-6.74, p=0.000). Students from the Random Word group suggested statistically significantly less breadth of ideas than students from the MATCEMIB (Z=-6.44, p=0.000) and the MATCEMIB+ group (Z=-5.50, p=0.000). Differences in the breadth of ideas generated by students from all other groups were not statistically significantly different.

The Kruskal–Wallis test on the differences in group creativity levels showed statistically significant differences in the creativity levels of students from the Control group and all three experimental groups: the Random Word group (Z=-2.83, p=0.005), the MATCEMIB group (Z=-7.36, p=0.000) and the MATCEMIB+ group (Z=-5.48, p=0.000). Independent assessors perceived students from the Random Word group as less creative than the students from the other two experimental groups: the MATCEMIB (Z=-4.43, p=0.000) and the MATCEMIB+ group (Z=-2.68, p=0.007). Differences in the creativity levels of students from the MATCEMIB and the MATCEMIB+ groups were not statistically significantly different.

No correlation between ATAR and the number of ideas, ATAR and the breadth of ideas as well as ATAR and the creativity level was found (Pearson Correlation). At the same time, the number, the breadth of ideas and the creativity level were well correlated with each other ($0.652<r<0.833$, p=0.000).

Table 3 presents statistical results for the number of independent ideas (Mean) generated by local and international students as well as the breadth of these ideas and the group's creativity levels. As shown in Table 3, Australian school graduates from all three experimental groups generated more ideas than their international counterparts.

Table 3: Number, Breadth and Creativity: local vs. international students

Group	N (*L* & I)	Mean	SD	Breadth	SD	Creativity	SD
Control	*108*	2.94	1.79	2.31	1.00	3.66	1.82
	40	3.20	1.76	2.32	0.92	3.33	1.39
Random W	*108*	3.99	2.50	2.67	1.28	***4.82***	2.30
	49	3.16	1.65	2.45	1.00	***3.76***	1.81
MATCEMIB	*87*	**6.00**	2.49	4.25	1.56	***6.29***	1.95
	25	**4.68**	2.14	3.80	1.63	***4.80***	1.78
MATCEMIB+	*95*	5.89	3.02	4.06	1.56	5.72	2.17
	65	5.31	2.33	4.08	1.50	5.11	1.72

The Shapiro-Wilk test identified that the distributions of the number of ideas, the breadth of ideas and creativity level shown in Table 3 was not normal for all eight groups. Therefore, the Mann-Whitney U test was used to evaluate differences in performance of local and international students. The number of ideas proposed by the students from the MATCEMIB groups differed statistically significantly (Z=-2.14, p=0.032). Although graduates of secondary schools outside Australia from the Control group generated more ideas than their local counterparts, this difference was not statistically significant. Differences in the breadth of the ideas proposed by local and international students were not statistically significantly different in all groups. At the same time, in the opinion of the independent assessors, local students from the Random Word and the MATCEMIB groups were statistically significantly more creative than their international equivalents (Random Word: Z=-2.67, p=0.008; MATCEMIB: Z=-3.13, p=0.002). Differences in creativity between local and international students from the other two groups were not statistically significant.

Discussion

Overall, the results of the idea generation experiment reinforce the previous studies showing the effectiveness of targeted ideation techniques (Belski & Belski, 2016; Buskes & Belski, 2017); namely, that students in the MATCEMIB and MATCEMIB+ groups statistically significantly outperformed students in the Control and Random Word groups in terms of the number of ideas generated. Furthermore, students in the MATCEMIB and MATCEMIB+ groups statistically significantly outperformed students from the Control group in terms of the breadth of ideas generated. Students from the Random Word group suggested statistically significantly less broad ideas than students from the other two experimental groups.

The first hypothesis has not been supported by this experiment. There was no correlation found between ATAR and the number of ideas, ATAR and the breadth of ideas or ATAR and the assessed level of creativity for all groups. The university that undertook the experiment has a relatively high ATAR entrance requirement and consequently there is limited variation of student ATARs in the experiment (mean 92.2, standard deviation 5.43). The tight range of ATARs might have made finding a correlation difficult. However, the observed lack of correlation, coupled with the observations of Buskes and Belski (2017) about the importance of prior science knowledge in idea generation, would indicate that secondary school academic performance (as measured by ATAR) is a weaker indicator of idea generation ability than simple exposure to more science subjects at the secondary school level. Students with higher levels of prior science knowledge could result in higher academic self-efficacy in science and, thus, more confidence in voicing ideas.

The second hypothesis has been partially supported. While graduates of secondary schools outside Australia from the Control group generated more ideas than their local counterparts and Australian school graduates from all three experimental groups generated more ideas than their international counterparts, only the difference for the MATCEMIB group was statistically significant. Differences in the breadth of the ideas proposed by local and international students were not statistically significantly different in all groups. It is not clear at this stage why the MATCEMIB experimental group appears to behave differently to the other experimental groups in terms of number of ideas generated and thus requires further investigation.

Local students from the Random Word and the MATCEMIB groups were judged by the assessors to be statistically significantly more creative than their international equivalents. For all groups, the number, the breadth of ideas and the creativity level were well correlated with each other and the fact the local students in the MATCEMIB group exhibited greater creativity might be due to the greater number of ideas generated than the international students. It is unclear, however, why the Random Word groups would exhibit such a difference in level of creativity. In the previous study (Buskes & Belski, 2017) it was postulated that the random words displayed to the students in the Random Word group may have affected international students differently and inhibited creativity. A similar effect could be at play in this case, which warrants further study.

Conclusion

The idea generation experiment appears to show that the ATAR score on its own is not an adequate criterion for idea generation performance in terms of number and breadth of ideas generated by students enrolled in the first year of the common science program at the Go8 university. When coupled with the previous idea generation experiment's results, prior science knowledge, as measured by the number of science subjects completed at secondary school, is a superior estimator for idea generation performance. Consequently, it is argued that prior knowledge in science needs to suitably assessed for assessment for entry into engineering degrees, where creativity and idea generation performance are increasingly seen as essential skills for an engineer to possess. It was also found that local and international students that belonged to the same experimental group were largely indistinguishable in the number and breadth of the ideas generated, save for the MATCEMIB group, where local students generated statistically significantly more ideas. The reason for this discrepancy is unclear and requires further study.

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