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FINDING OCCUPATIONAL INJURY SOLUTIONS: THE IMPACT OF TRAINING IN CREATIVE THINKING

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Abstract–Enhancing expertise by way of training in health and safety is a common approach in injury prevention. The rationale is that providing people with an understanding of health and safety enables them to better conduct prevention programs. Given the pre-eminent role of engineers in design and the contribution to be made to safety though good design, there are regular calls for engineers to have more safety education. However, integration of new material is difficult in already crowded engineering curricula. Current management trends are emphasising the importance of creativity. Within this climate, we propose that training engineers in creative thinking may improve their skills in injury prevention. Compared to safety-specific knowledge, creative thinking methods may be easier to integrate with engineering studies because of their contemporary meaning and wide applicability. To test this hypothesis we trained undergraduate engineering students of the University of Ballarat in creative thinking based on de Bono's *Six Thinking Hats* method. We tested their ability to generate solutions and make decisions about hazard control options. The results show that training in creative thinking improves the ability to generate solutions and improves the ability to prioritize solutions in terms of their prevention potential. These effects are evident when people work alone or work in a team of three. © 1997 Elsevier Science Ltd.

1. Injury prevention from Heinrich to hierarchy: Historical perspective and safe-place theory

In 1931 H.W. Heinrich published the first edition of his text, *Industrial Accident Prevention* (see Heinrich, 1941). Heinrich based this influential work on his analysis of insurance statistics in the 1920's to find the causes of accidents. As was common at the time, Heinrich attributed accidents to either unsafe acts or unsafe conditions. Based on this model of causation, Heinrich blamed 88% of accidents on *unsafe acts*, 10% on *unsafe conditions* and said that two percent were unpreventable and without apparent cause. To explain the accident process, Heinrich proposed the *domino* model in which five factors occurred to result in injury. The central factor in the sequence was the *unsafe act* or *unsafe condition*. Since unsafe

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acts were the cause in 88% of cases, Heinrich stressed that avoiding unsafe acts was the best way to prevent injuries. Heinrich's theory has enjoyed popular support, for example,

> *... Heinrich informed us of what is now painfully obvious and simple truth-that people, not things, cause accidents* (Petersen, 1978, p. 15).

Unfortunately, this model reinforced and legitimised a preoccupation with behavioural elements such as *human error* and *unsafe acts* as the cause of most injuries and subsequently reduced emphasis on design of the environment. The approaches to prevention that followed the *unsafe acts* theory, have thus focussed on modification of the behaviour of potential victims, however it is now widely recognised that this is rarely successful.

> *Only very limited, if any, control is possible by focussing on the behaviour of those who may be injured.* (Industry Commission, 1995, p. xx)

While the philosophy that followed the work of Heinrich has been popular, there has been an alternative approach to the management of hazards. Sometimes known as the *safe-place* theory (Atherley, 1975), this approach aims at the control of hazardous conditions in ways that rely as little as possible on the appropriate behaviour or vigilance of potential victims. This way of thinking is often described as a *hierarchy of controls*; a guide to prevention that focuses first on management of the hazard and lastly on the behaviour of those at risk. The model shares a strong relationship with previously established concepts in the control of occupational diseases. It had been customary in occupational hygiene to view the source of contamination as the hazard source and to regard the control of the hazard source as a priority (Hamilton, 1929). The problem of occupational hygiene was conceptualised as follows:

hazard source → transmission pathway → recipient.

Hamilton, recognised as a pioneer figure in the establishment of the hygiene profession, made it clear that controlling the source of the problem was the only reliable way to prevent occupational diseases. The importance of controlling the source was easy to conceptualise with this model and led to the *hierarchical* models of control (Table 1, Bloomfield, 1936; Brandt, 1947). The application of this model to the prevention of injury soon followed (Table 2, National Safety Council, NSC, 1959; Haddon, 1963).

> *The engineer should include in his planning and follow-though such measures as will attain one of the accident prevention goals listed as follows (in the order of effectiveness and preference) ... .* [See Table 2] (NSC, 1959, p. 4-2)

The hierarchy of control is now a general approach to health and safety and many government regulations state that the hierarchy is the preferred model for prevention. There is a vast number of versions all based around the following basic methodology.

1. Eliminating or minimising the hazard source.
2. Containing the hazard source.

Table 1
Hierarchies for the prevention of occupational diseases

Bloomfield (1936)	Brandt (1947)
1. Substitution of a non-toxic material for the toxic one	1. Eliminating the sources of contamination or reducing the amount
2. Isolation of the harmful process	2. Prevention of contaminant dispersion
3. Wet methods in the case of some dusty processes	3. Protecting the worker
4. Exhaust ventilation	
5. Respiratory protection	

Table 2
Hierarchies for the prevention of occupational injury

NSC (1959)	Haddon (1963)
1. Eliminate hazard	1. Prevent marshalling of energy
2. Minimise hazard source/prevent release	2. Prevent or modify the release of energy
3. PPE	3. Remove the man from the vicinity of the energy
	4. Impose a barrier

3. Separation of the hazard and people (by barriers, distance, etc.).
4. Protecting the worker with PPE.

Sometimes the hazard source is thought of as a damaging energy, an approach mainly due to the work of Gibson (1961) and Haddon (1963), and later made popular through the risk management models by Johnson (1973, 1980). While the energy approach gives greater precision to the definition of hazard, the approach is not universally accepted, and often the hazard is considered using more general definitions such as: "*potential to cause injury or illness*" (NOHSC, 1994, p. 5).

While the relative order and precision of the terms in the hierarchy can often be argued, the core theme of the hierarchy of control model is that emphasis should be directed toward control of the hazard in preference to addressing the behaviour of the person at risk. Controls should be reliable without the vigilance of operators or others at risk. These controls are sometimes referred to as passive controls, they act to control the hazard without the active involvement of those at risk.

2. The role of engineers

Given their influence over design, and the need for safety to be incorporated at the design stage, the education of engineers in the principles of safety has been a priority for many years. For instance the UK report known as the Robens Report, and the US NIOSH report on improving engineering education, made the following comments.

> *... professional engineering institutions could make their concern with the subject much more explicit by including safety and health as an item in their syllabuses and examinations.* (Committee on Safety and Health at Work, 1972, p. 127)

> *Engineering students should be made aware of occupational safety and health responsibilities, problems, and control techniques as undergraduates; the comprehensive practice of occupational safety and health engineering should be taught at the graduate level.* (NIOSH, 1984, p. 28)

In Australia, the importance of the education of engineers has been recognised by the *National Education and Training Strategy for Occupational Health and Safety* (NOHSC, 1993), and by the Institution of Engineers, Australia (IEAust), who emphasise the importance of safety as a key ethical requirement of engineers. In its *Code of Ethics* the IEAust outlined nine tenets of the ethical behaviour (IEAust, 1994). The importance of safety in engineering is the *first* tenet of ethical engineering.

> *Members shall at all times place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests, or to other members.* (IEAust, 1994)

Since around 1980 a number of universities such as Purdue University, and Ohio State University, in the United States (Talty, 1986), Delft University of Technology in the Netherlands (Lemkowitz, 1992), and the University of Ballarat here in Australia (Woolley and Viner, 1980) have integrated safety topics with engineering studies. In addition, there have been wider efforts such as the NIOSH (USA) *Safety and Health Awareness for Preventative Engineering* program that began in the 1980's (Talty, 1995) and more recently, Worksafe Australia's *OHS for Engineers* program (NOHSC, 1990b; Cowley and Murray, 1991).

Training engineers in health and safety is a commonly advocated strategy in injury prevention. The rationale is that this specialist knowledge enables safer design. However, while the integration of safety with engineering education is desirable it has generally been poor (Hale, 1994). Integration of safety is difficult due to an already overcrowded engineering curricula and one that is facing increasing rather than decreasing pressure for the inclusion of material (OTA, 1985; Talty, 1986). The challenge therefore is to explore additional methods of improving the ability of engineers to develop safe-place solutions to safety problems.

3. The need for creative thinking

Interventions such as Worksafe Australia's *OHS for Engineers* program concentrate on safety as an independent subject. This safety knowledge is clearly the basis for safe place controls, however safe place design would seem to require more than safety knowledge for its implementation. The *elimination* step, which is usually first on the hierarchy, is conceptually very challenging. It requires that assumptions be re-thought, the very operation of the system must be examined. It is very tempting to avoid this approach and select solutions that require less conceptual rethinking and thus appear immediately attractive and expedient. However, the conceptually less-challenging approaches to prevention usually involve add-ons like safe behaviour programs or personal protective equipment. Safe place design is not easy, it doesn't involve add-ons, it involves a redesign of how things work. Furthermore, the safe place approach demands a shift in thinking from an established paradigm of the role of unsafe behaviour in accident causation. A rethinking of the assumptions of human fault, as discussed by Wigglesworth (1978) and Kletz (1985) is necessary to refocus designers on passive controls. The focus on human fault in accident analysis can block safe place solutions, for instance why would engineers attempt safer design if they believe faulty human behaviour causes 88% of accidents? If the human fault premise exists then it appears as though behaviour-change programs are the best vehicle for prevention. Escape from these popular paradigms requires creative thinking.

The ability to be creative when developing safety solutions is mentioned by some authors as a key element in injury prevention (for example, Kletz, 1988, 1990; NOHSC, 1990b; Hale, 1994). The core need for this skill would seem to arise from the conceptually difficult approach indicated by the hierarchy model. This same challenging type of thinking has been the key focus for the study of creative thinking. Thus there are established methodologies that can be employed to make the task of redesigning for safety an easier one.

It has long been recognised that creative thinking is characterised by a change in assumptions, a change of paradigm, a new way of looking at things, thinking outside the square, or thinking laterally. Within this model of creative thinking it is also well recognised that the basic operations of thinking are more suited to staying *inside the square*. Many authors over a vast span of time have written that the ordinary operation of the mind is deigned to think un-creatively (for example, Locke, 1882, c.1680; Hume, 1910, c.1740; Dewey, 1910; Spearman, 1930; Osborn, 1948; Gerard, 1952; de Bono, 1969; Gardner, 1985; Adams, 1987; Rickards, 1988; Sternberg and Lubart, 1995).

Given this essential uncreativeness a number of techniques have emerged as central to the process of deliberately diverting the mind from the dominant way of thinking. Among these are the techniques of *random combinations* (Mednick, 1962; de Bono, 1977), *analogy* (Ribot, 1906; Gibson and Phillips, 1958; Gordon, 1961; Koestler, 1969; de Bono, 1971; Bransford and Stein, 1984), *morphology* (Allen, 1962; Zwicky, 1969; Koberg and Bagnall, 1981; Adams, 1986; Rickards, 1988) and the *focussing verbs* such as *reverse*, and *magnify* (Osborn, 1948).

While these *deliberate diversion* techniques are widely cited there are only isolated reports of research into their effectiveness, such as Bouchard's (1972) investigation of the technique of *personal analogy* (see Bouchard, 1972; Gordon, 1961). For some problems in the experiment, Bouchard found that the method was very effective, but for other problems there was no effect.

In contrast, the broader technique of brainstorming has been studied fairly extensively and training in this method has been shown to be an effective way to boost creative performance (Meadow and Parnes, 1959; Parnes and Meadow, 1959; Reese and Parnes, 1970; Baer, 1988). Others have examined the effect of encouraging subjects to use the few simple steps of brainstorming (without the benefit of training), and found this to be a productive intervention (Parnes and Meadow, 1959; Meadow et al., 1959; Weisskopf-Joelson and Eliseo, 1961; Parloff and Hanson, 1964; Szymanski and Harkins, 1992). Further studies have showed that the components of brainstorming are valid by showing that influences like criticism (Smith, 1993) or the potential for evaluation (Diehl and Stroebe, 1987) have a negative effect on idea productivity. The brainstorming model invites a free-flowing approach to the generation of ideas. Some studies have shown that treating a topic as frivolous has been shown to be beneficial as these types of topics lead to greater brainstorming performance (Harari and Graham, 1975; Maginn and Harris, 1980; Diehl and Stroebe, 1987). In contrast a number of studies have failed to find any effect for one aspect of the supposed value of the brainstorming model, the effect of *idea-stimulus*. It was thought that brainstorming was valuable partially because of the boost to idea generation gained by the presence of many other ideas (idea-stimulus), however this has not been shown in studies that attempted to isolate this effect (Madsen and Finger, 1978; Connolly et al., 1993; Paulus et al., 1993).

While many of the techniques of creative thinking that are widely promoted are not equally well researched as brainstorming, there is clearly an established body of knowledge and techniques that may be applicable to the area of safety. While providing engineers with knowledge in all relevant areas will become increasingly difficult due to the demands on their education, training in creative thinking may be attractive given its potential application in many areas of their work. Enhancing skills in creative thinking would also be in keeping with contemporary industrial changes. For instance, Arie De Geus of Royal Dutch/Shell says that *"The ability to learn faster than your competitors may be the only sustainable competitive advantage."* (in Senge, 1992) and the Australian Manufacturing Council Secretariat point out that *"Innovation will be the next source of substantial growth."* (AMC, 1994, p. 1).

4. Hypothesis

We posit the hypothesis that training in creative thinking can improve ability in injury prevention. Creative thinking tools are attractive as a potential means for facilitating improved safe design for a number of reasons:

1. The need to re-conceptualise systems to achieve safe place design would seem to be closely related to established concepts and methods of creative thinking.
2. The wide applicability of creative thinking tools make the learning of these methods more appealing than education in safety-specifics.

5. Methodology

To test the hypothesis, we trained and tested undergraduate engineering students in creative thinking. The methodology for the research is shown in Fig. 1. Forty-two fourth-year undergraduate engineering students at the University of Ballarat voluntarily took part in the research. All subjects took part in a one-day training program in creative thinking, based on the six thinking hats technique (de Bono, 1985, 1992), described below. The six thinking hats method encapsulates many techniques of creative thinking, such as, the deliberate challenging

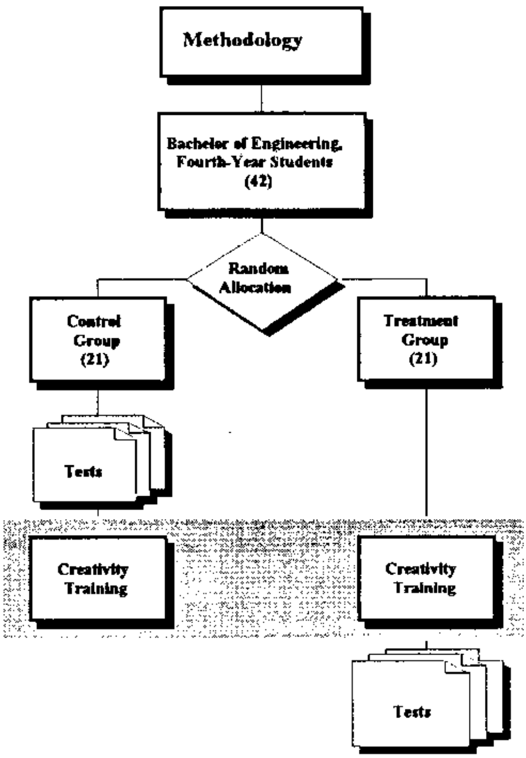

Fig. 1. Methodology.

Table 3
Six thinking hats (de Bono, 1985)

Metaphor	Focus of thinking
Green hat	Creativity, alternatives, possibilities
Yellow hat	Benefits, values, opportunities
Black hat	Caution, risks, judgement
Blue hat	Control, managing the thinking
Red hat	Emotion, feelings, intuition
White hat	Information, facts, data

of assumptions using prompts such as the *reversal* technique, and the *combination* technique using inputs such as the *random* word technique, within a broad framework for thinking.

As Table 3 shows the method provides a structure to organise and direct thinking using the hats as a metaphor. The hats provide a simple mechanism to generate more focussed thinking and greater thinking clarity. The method encourages a fuller range of thinking. For instance, criticism and judgement are essential to our thinking, but often dominate at the expense of other types of thinking, such as creative thinking.

Some research studies with school children of the CoRT (Cognitive Research Trust, de Bono, 1982) program that employs de Bono's methods indicate that the methods are effective (Edwards and Baldauf, 1982; Ruffels, 1986; Edwards and Baldauf, 1987; de Sánchez, 1987; Eriksson, 1990; Edwards, 1991), however there appears to be no evidence of any testing of these methods with designers or engineers.

The training was conducted by John Culvenor (co-author) who was qualified to teach this material having completed a one week intensive course lead by Edward de Bono. Given that the purpose of the training was to test the potential link between training in general creative thinking skills and the specific problem of safety, the training purposely excluded the subject of safety. The subject of safety did not arise in any way and was not part of any examples, or case studies, or any training materials.

Half of the subjects were selected at random before the training and completed a test as the control group (untrained). At the completion of the training the other half of the group took the test as the experimental group (trained). There was no test administered to establish the equality of the randomly arranged groups. It was assumed that given a relatively homogenous population (all fourth-year engineers at the university) that the random allocation would result in groups of reasonably equal ability.

Often work in teams and teamwork is a common focus for management today (for example, Senge, 1992; Peters, 1994), therefore we evaluated the performance of subjects in teams as well as individually.

5.1. Evaluation of the training

Most training programs evaluate the *subjective* usefulness of the training and quality of presentation. However as Hale (1984) points out in his paper, *Is Safety Training Worthwhile?*, training programs often lack evaluation in terms of their impact on *performance*.

It has become established in the assessment of creative thinking to measure responses to a case study problem in terms of, a quantitative measure (idea fluency or the number of ideas), and qualitative measures (often called originality, flexibility, etc). This model forms the basis

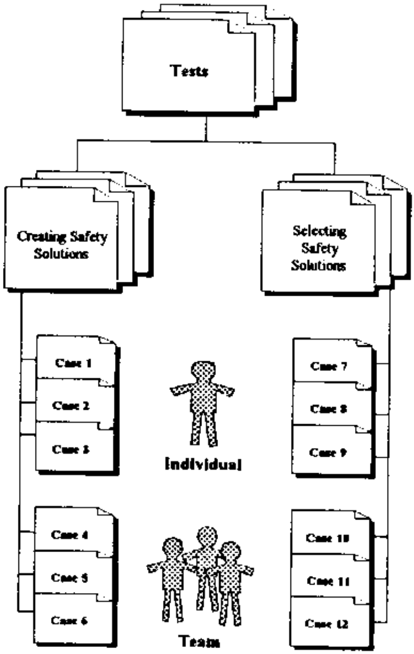

Fig. 2. Case studies.

for the popular Torrance Tests of creative thinking (Torrance, 1974) and stems from the work of Guilford (1950). Whether using a standard test like the Torrance Test, or a self-designed test, this model of assessment is widely accepted. For the research here we adapted this model to the subject of safety, by using safety problems as the case study material, and by assessing the qualitative value of the ideas subsequently generated according the to hierarchy of control model.

An additional measure involved presenting subjects with an accident case study, and requiring them not to generate ideas, but to prioritize a given list of ideas according to their potential effectiveness in prevention of the injury. The ability to prioritize solutions has been rarely measured in studies of creative thinking, but would seem to be worthwhile in this area. For instance Worksafe Australia (NOHSC, 1990a) identified that in terms of research in engineering and technology interventions for the prevention of mechanical equipment injury, the means for improving safety should focus on *new approaches* to safety problems (generate solutions) and also the *application* of *known* safety measures (prioritize solutions). For the application of known ideas, one needs be able to select those ideas with the greatest potential for prevention.

In summary, the key abilities assessed in this research were:

1. The ability to *generate* alternative safety solutions.
2. The ability to *prioritize* safety solutions given a list of options.

As has been the common approach in the assessment of creative thinking, a set of case studies were devised and tasks designed around the abilities above. The case studies covered a

Table 4
Case studies

Case studies
1. Grain worker and the rail carriage
2. Lawyer and the coconut tree
3. Motorist and the car
4. Sawyer and the circular saw
5. Mining supervisor and the dump truck
6. Bank manager and the chain saw
7. Aircraft fitter and tug
8. Gardener and the gang mower
9. Cable laying contractor and the bogged utility
10. Orchardist and the power line
11. Transport worker and the falling pipes
12. Production engineer and the forklift

Table 5
Tasks and measurements

Case	Task and key ability	Measurement
1–6	Suggest risk control options (5 min per case)	Number of solutions and proportion 'safe place' solutions
7–12	Rank six risk control options from most effective to least effective (2.5 min per case)	Correlation with optimum rank

range of situations and were all fictional. The tests (Fig. 2 and Table 4) presented subjects with injury case studies. The task for the first six cases (see example, case one, Appendix A) was to suggest solutions to prevent the injury. The second part of the test was based on the ability to *prioritize* control options in terms of their injury prevention potential. Each case study in the second half of the test (cases 7–12) had six control options listed (see example, case eight, Appendix A). The task was to rank the options from most effective to least effective. The measure of success was the correlation of the rank with the *optimum* rank we developed. We assessed the validity of the optimum ranks by comparing them with the opinions of five OHS experts. Five lecturers in health and safety at the university completed the test and their ranks correlated well with the optimum (correlation, $r = 0.8–1.0$). (See Table 5.)

6. Results

6.1. Generating alternative safety solutions

The results show a strong relationship between training in creative thinking and the ability to generate alternative solutions to health and safety problems (Table 6). Figures 3 and 4 show that for teams and for individuals the trained group outperformed the untrained group by about one hundred percent. These changes were all significant and consistent across the different case studies.

Table 6
Number of alternative solutions: Trained and untrained subjects

Case	Mode	Untrained			Trained			t-test
		Ideas	N	SD	Ideas	N	SD	'p'
One	Individual	4.9	21	1.8	9.0	21	2.9	0.000
Two	Individual	4.9	21	2.2	11.9	21	3.8	0.000
Three	Individual	4.4	21	1.7	11.3	21	4.4	0.000
Four	Team	7.3	7	2.7	15.4	7	3.9	0.000
Five	Team	7.9	7	2.6	17.3	7	3.1	0.000
Six	Team	7.6	7	3.0	19.1	7	6.5	0.000

To move forward in prevention then we need to encourage more creative thinking, more possibilities for change. However, thinking creatively is not always easy for people. Cowley (1990) commented that while analysis is important in injury prevention, generating solutions is vital. Describing, measuring and criticising an existing system is much easier than designing a

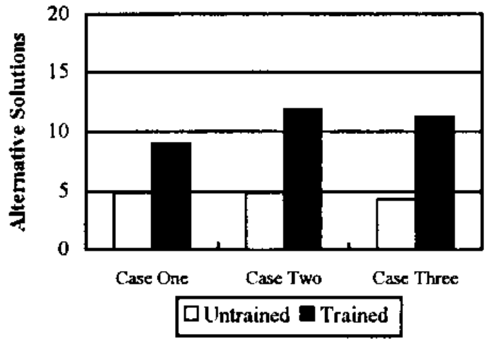

Fig. 3. Number of alternative solutions to safety problems generated individually: Trained and untrained subjects.

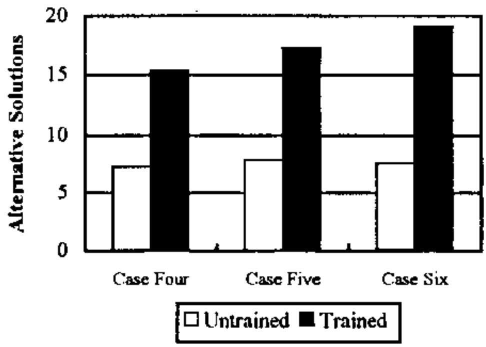

Fig. 4. Number of alternative solutions to safety problems generated in teams: Trained and untrained subjects.

Table 7
Proportion of safe-place solutions: Trained and untrained subjects

Case	Mode	Untrained			Trained			*t*-test
		%	*N*	SD	%	*N*	SD	'*p*'
One	Individual	72	21	22	63	21	25	0.113
Two	Individual	58	21	22	67	21	13	0.057
Three	Individual	53	21	28	58	21	20	0.294
Four	Team	54	7	15	60	7	8	0.190
Five	Team	37	7	10	49	7	16	0.054
Six	Team	56	7	11	64	7	9	0.080

new system. Training in creative thinking, appeared to dramatically improve the ability to develop alternative solutions to safety problems.

6.1.1. The quality of the solutions

More ideas seem valuable as they allow greater choice of action, however they are only useful providing the quality of the ideas is maintained. To assess idea quality we estimated the proportion of safe place solutions within a set of responses by classifying those solutions against lists of *potential solutions* split into two categories, safe place and safe person (for example see case one, Appendix A). The results (Table 7, Figs. 5 and 6) showed that the proportion of safe place ideas was not different between the trained and untrained group. Since the proportion of safe place ideas remained steady with the improved number of alternatives, the trained group generated a much greater *actual number of safe place* solutions. The application of creative thinking methods thus lead to a larger set of potentially effective options from which to choose.

6.2. Prioritizing safety solutions

Results show that training in creative thinking has a positive impact on the ability to prioritize given safety options (Table 8). Figures 7 and 8 show that on most cases the trained

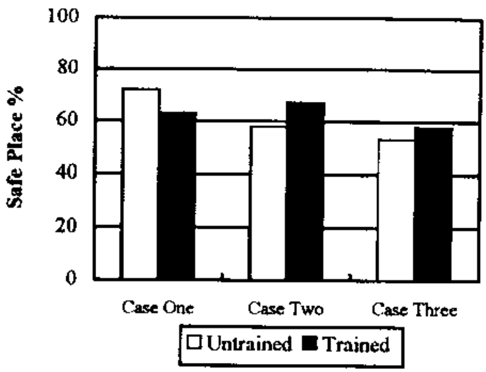

Fig. 5. Proportion of safe-place solutions working individually: Trained and untrained subjects.

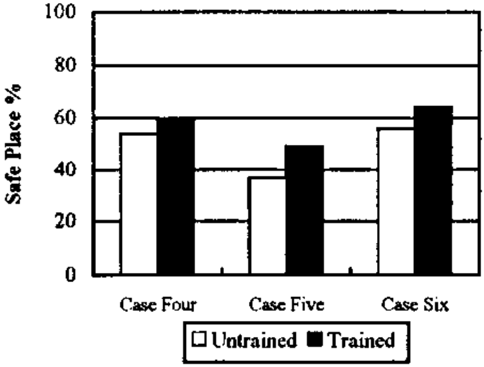

Fig. 6. Proportion of safe-place solutions working in teams: Trained and untrained subjects.

Table 8
Mean correlation with optimum rank: Trained and untrained subjects

Case	Mode	Untrained			Trained			*t*-test
		r	*N*	SD	*r*	*N*	SD	'*p*'
Seven	Individual	−0.288	21	0.449	0.093	21	0.578	0.011
Eight	Individual	−0.081	21	0.504	0.143	21	0.525	0.083
Nine	Individual	0.342	21	0.513	0.605	21	0.405	0.037
Ten	Team	−0.004	7	0.329	0.447	7	0.557	0.045
Eleven	Team	0.379	7	0.242	0.763	7	0.245	0.006
Twelve	Team	0.830	7	0.185	0.864	7	0.131	0.360

subjects performed significantly better than those untrained subjects. It must be remembered that the scale of −1 to +1 represents a full range of opinion from that which accords to the safe place philosophy (+1) to that which is the reverse of this ideal, representing a

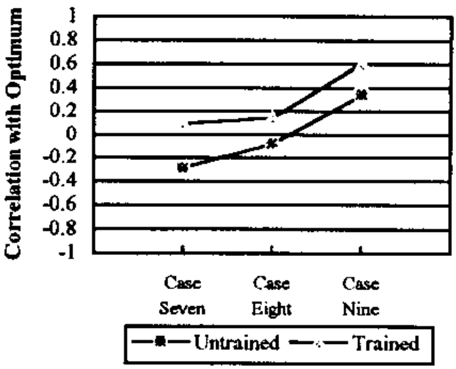

Fig. 7. Correlation with optimum ranking of a set of solutions to a safety problem working individually: Trained and untrained subjects.

safe-person philosophy (-1). The better scores of the trained group were evident both for subjects working individually and when working in teams of three. The untrained group performed near to the optimum on case twelve and so there was little scope for improvement in the trained group.

While the generation of alternative solutions is important there comes a stage when decisions have to be made about which control strategies will be most effective. Being able to generate useful ideas is valuable and an important part of the research, however, the skill of discriminating and prioritizing options in terms of their injury prevention value is also important. The research here showed that the ability to prioritize solutions improved following training in creative thinking. These effects need to be considered in terms of the existing knowledge base of the students. Because of VIOSH-Australia's involvement in the University of Ballarat engineering course, the students who took part in these experiments would have been likely to have a stronger basis in health and safety than most engineering students. Given this basis of understanding, creative thinking methods were an effective vehicle in improving the ability to prioritize solutions.

7. Discussion

Much of the difficulty of creative thinking is the exclusion of judgmental thinking and criticism. Osborn (1953) described criticism as *cold water* on ideas while cooperation and improvement of other people's ideas was the hallmark of successful creative teamwork. Within the training there was discussion and exercises that emphasised how the dominance of criticism in our thinking and the seemingly natural tendency toward argument in our culture form blockages to creative thinking. Some research has shown that being critical offers a prestige advantage (Amabile, 1983). Amabile showed that those who more are critical are perceived as being more intelligent by their peers. Given this finding there is a good reason for people to be critical, they appear smarter. However the presence of criticism is not seen as a useful feature of creative efforts. The early self-evaluation of ideas (Sappington and Farrar, 1982) and the injection of external criticism (Smith, 1993) has been shown by research studies to impede creative performance. Even *apprehension* about the prospect of being evaluated by others reduces the output of idea generation (Diehl and Stroebe, 1987). Trained subjects with greater awareness of this effect may have minimised criticism when generating ideas. Obviously this has particular application to group thinking, but it is also plausible that individual thinking could be aided by adopting a less critical approach even of one's own ideas.

The exclusion of criticism may have been further facilitated by the way that the six hats model encourages a separation of thinking tasks into bite-size activities. When green hat thinking it was important that only new possibilities, creative thinking, etcetera was undertaken at that time. This focussing ability may have translated into more intense thinking about ways to prevent the injury occurring rather than analysing the problem, or criticising ideas already developed.

Furthermore, the training emphasised that the subjects should take specific control over

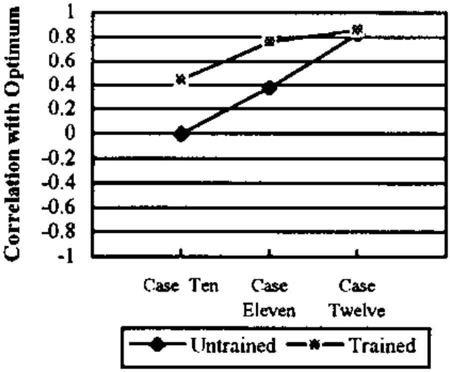

Fig. 8. Correlation with optimum ranking of a set of solutions to a safety problem working in teams: Trained and untrained subjects.

their own thinking and *choose* what type of thinking was appropriate at a certain time. Subjects were encouraged to consider situations by overviewing the problem and then making planning decisions about what kind of thinking would be most beneficial for this situation. In their characterisation of *lifelong learners*, Candy et al. (1994) describe this kind of skill as *helicopter* vision. The encouragement of helicopter vision, or perhaps helicopter thinking, could have been worthwhile feature of the training by enabling subject's to *see* what type of thinking was appropriate, a subsequently focus on this type of thinking.

The training involved short periods of intense thinking. This may have created a belief in the subjects that they are able to do productive thinking in a short time. If subjects gained an enhanced expectation of their own ability then this may have translated into improved performance. While there is little research directly into the effect of *perception of ability* on idea production, a few research studies have assessed the effect of setting goals, which may be related. For instance Latham and Saari (1979) and Locke (1982) found that goal setting had a positive effect. However, later, after improving on some methodology problems in Locke's study, Lorenzi (1988) failed to show that goal-setting made any difference. The effect of goal-setting would not necessarily be the same though as the effect of a higher perception of ability. Therefore it may still be true that enhancing a belief self-ability would lead to positive effect on performance.

Some research has shown that the difference in the performance of brainstorming groups and non-brainstorming groups was due to the large amount of ideas that the group actually thought of but failed to recognise as worthwhile ideas (Parloff and Hanson, 1964). It would seem then that encouraging participants to recognise the value in ideas would be worthwhile in improving creative performance. The training emphasised that value may ultimately be found in ideas that initially seem valueless. Judgement of the ideas should be delayed and in addition some specific effort should be made to find value in the ideas and develop them into something useful. Often during the training it was emphasised and demonstrated that some value can often be found in ideas that initially appeared useless. This demonstration may have created an openness to the exploration of possibilities and lead to greater recording and building upon otherwise discarded ideas.

As mentioned above, the minimisation of criticism and the enhancement of cooperation is important in creative thinking. In groups, the six hats model provides a structure to facilitate a cooperative approach to thinking. The emphasis in the training was on each person in a group thinking with the same hat. In particular, this seems to free those who feel as though they should provide a cautioning role, to be involved in idea generation.

Finally, the training emphasised that it is possible to use techniques to generate ideas. Participants learnt and practiced using these techniques to assist the generation of ideas. While this processes is linked to other elements such as the reduction of criticism, cooperation, and an openness to ideas, it is not just these factors that are important. Participants hopefully completed the training with some understanding of how to employ simple techniques to get thinking moving quickly. There is little background research about the effectiveness of such methods. Bouchard (1972) compared brainstorming groups using the analogy technique with those not using the technique. The results were not clear, in one instance those using analogy generated 100% more ideas, however this did not occur for all problems in the research. While research about the use of deliberate techniques of *thinking diversion* is minimal, they are widely cited as important features in creative thinking and so one would expect that developing a skill in the methods could lead to improved performance.

In summary the mechanisms within the training in the research here that would seem to have facilitated improvement in creative output are:

- encouraging more focussed thinking;
- encouraging metacognition, or helicopter vision;
- creating a belief in the ability to perform at a high level;
- encouraging the minimisation of criticism;
- providing a structure for thinking that facilities a reduction in criticism;
- encouraging an openness to the possibility of alternatives and the value in ideas;
- encouraging and providing a structure for cooperation in teams;
- developing a skill in the techniques of idea generation.

8. Conclusion

Injury prevention is best achieved with safe place systems. Safe-place systems are those that maintain control of hazards without relying heavily on the vigilant behaviour of those at risk. These controls are sometimes known as *passive* controls as for their success they do not rely on the *active* involvement of the people at risk. To achieve safety by way of the safe-place, or passive, approach, safety knowledge is obviously important to those who are in a position to design and implement these systems. Training engineers in safety theory appears worthwhile because engineers are able to influence design. However, including safety within increasingly crowded engineering curricula is difficult.

The results here show that creative thinking training improved the ability of undergraduate engineers to generate alternative solutions to safety problems. The magnitude of this improvement was approximately one hundred percent and was achieved without any drop in the quality of the solutions. Training in creative thinking was also shown to improve the ability of the engineers to prioritize solutions in accordance with the safe place philosophy. These results were equally valid for individuals and for teams. Creative thinking and learning appear to be key competencies for the future and vital for organisations to be successful in the global marketplace. This research shows that within this climate, creative thinking can be an effective *lateral* method for improving injury prevention.

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Appendix A

A.1. Examples of case studies and examples of standard classifications for solutions (Case One) and examples of options (Case Eight)

A.1.1. Case One: Grain worker and the rail carriage

Kim worked as a labourer in a grain processing plant. He severely damaged his neck and shoulder manually moving a rail carriage back onto its rails.

The rail car carried grain around the inside of the factory. A hand crank on one of the wheels drove the car. The flanged wheels ran on rails embedded in concrete. Often the cars became derailed due in part to; the unbalanced single-wheel drive, poor wheel bearings and an uneven track joined for factory extensions.

On the day of the accident the car derailed between work shifts. Kim tried re-railing the car on his own. Two people normally use levers to raise the car onto blocks and then push it back on the tracks. The company now specifies the re-railing of grain cars as a team-lifting task.

Safe-place solutions

- *Other products (no grain)*
- *Different layout (don't move grain around)*
- *Conveyor (no trolley)*
- *Vacuum system (no trolley)*
- *Forklift (no trolley)*
- *Two-, or four-wheel drive trucks (less derailment)*
- *New track (less derailment)*
- *New wheel bearings (less derailment)*
- *Rubber tyred carriages (no derailment)*

Cut-off point

- *Small trolleys (less derailment, easier to re-rail)*

Safe-person solutions

- *Re-railment jacks, crane (just as much derailment, easier to re-rail)*
- *Maintenance of current system (maybe less derailment)*
- *Training (making sure people know what to do)*
- *Safe-work procedures (making sure people know what to do)*
- *Teamwork, rostering (making sure two people are on hand)*

A.1.2. Case Eight: Gardner and the gang mower

Kelly is a gardener at a metropolitan hospital. Kelly was cleaning a 'gang' mower when she cut her foot. Kelly had seen other gardeners clean the mower by hosing the blades with water while operating them in reverse. Kelly was washing the mower in this way when her left foot touched the moving blades. The blades left deep cuts in her big toe and two adjacent toes.

There had been no verbal or written instruction about how to wash the mower safely. The hospital provides safety boots but Kelly was not wearing them at the time of the accident. Often outdoor workers wear their own shoes claiming that they are more comfortable. The hospital has now developed a code of practice for the safe operation of the gang mowers.

Options

- *Provide training in the new code of practice*
- *Remind all outdoor staff to wear safety boots*
- *Use sheep to graze the grass*
- *Purchase a self cleaning mower*
- *Re-sow the grass with a slower growing native variety*
- *Provide training away from the workplace in hazard recognition and reporting*