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TRIZ Training Within a Continuous Improvement (Kaizen) Event – Exploration and Evaluation

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Abstract.

This paper discusses the implementation and evaluation of an online-based TRIZ training that was simultaneously conducted within a Kaizen (continuous improvement) event. The purpose of the training was to introduce and show the application of TRIZ tools using a real problem that was undertaken as part of the Kaizen exercise. The problem was a software related problem. The TRIZ tools that were presented in the training were Situational Analysis (SA), Functional Modelling (FM), Cause and Effect Analysis (CEA), Substance-Field (SF) Analysis, 40 Inventive Principles, Patterns of Evolution and Function Oriented Search (FOS). The research questions investigated were: 1) *Can combining a TRIZ training within a Kaizen event which was conducted online, result in an effective training session?* and 2) *Which TRIZ tools that were presented during the event were perceived by the participants to be the most useful and which ones were the least useful when delivered in this manner?* It was found that embedding the TRIZ training in the online Kaizen session was well-received and considered effective. It was identified that participants in the study prefer TRIZ tools that assist in problem identification. Areas of improvements were also sought from the participants' responses. The study has implications for organisations wishing to develop in-house TRIZ training.

Keywords: TRIZ training, engineering professional development, kaizen, problem solving, self-efficacy, evaluation, action research, online training

1 Introduction

The value of staff training within an organisation is well documented. Training can bring about several benefits including boosting the morale of employees, staff-retention, increasing and improving performance and productivity as well as bringing about innovation and long-term profit for the organisation [1-4]. While the value is undeniable, training and staff development is an investment that can be costly. Thus, it is important that training activities are implemented properly.

This paper describes the implementation of an online-based TRIZ training within a global large-sized company based in Melbourne, Australia. The company has a strong focus on problem solving and formally includes TRIZ within its recommended

problem-solving tools repertoire. This has allowed for opportunities to formalise in-house TRIZ training within the organisation. This study is a continuation of the exploration on how TRIZ training can be effectively implemented within this organisation.

The challenge of deploying successful TRIZ training was discussed by Ilevbare et.al. who identified that barriers to TRIZ uptake are the complexity of TRIZ tools and the time consuming nature to understand the application [5]. In their literature review on the usage of TRIZ tools, Sojka and Lepšik also reinforced the same challenges in effectively teaching TRIZ [6]. In addition, Gadd found that the uptake of TRIZ can be limited too if the organisation does not provide enough opportunities to utilise the tools [2]. It can be summarised that the challenges for an organisation wishing to implement TRIZ training are: 1) Time; 2) Complexity and; 3) Opportunity to use the tools in real context. The use of a real problem in the Kaizen session within the organisation in this study provided a good opportunity to address these issues.

The aim of this research is to evaluate an implementation of a TRIZ training which was embedded within an online-based Kaizen event. The research questions explored in this paper are:

1. Can combining a TRIZ training within a Kaizen event which was conducted online, result in an effective training session?
2. Which TRIZ tools that were presented during the event were perceived by the participants to be the most useful and which ones were the least useful when delivered in this manner?

2 Embedding TRIZ training within a Continuous improvement – Kaizen event

Several previous attempts to introduce TRIZ training within the organisation have been undertaken. One such implementation was a survey style online-based training which participants complete at their own time [7]. It was observed that participation was high initially. However, participation dropped off dramatically when the engineers were asked to go through materials and exercises covering the 40 Inventive Principles. In addition, the exercise was not formalised or mandated. One of the main feedbacks received was that more guidance during the training was preferred [7].

Learning from this experience, it was clear to improve the training, formalisation was needed. However, similarly, it was ideal if the training did not take extra time from the engineers but could be incorporated within their current work tasks. Hence, a training within a Kaizen event was trialed. The Kaizen event took place via Zoom due to Covid-19 restrictions. It is expected that the online mode of learning will continue as Covid-19 has changed the way the organisation operates, allowing for remote working arrangements. In addition, given that the organisation involved is a global one, it is expected that the training will involve engineers from multiple sites.

Kaizen is a Japanese word that indicates a process of continuous improvement of the standard way of work [8]. It is a compound word involving two concepts: Kai (change) and Zen (for the better) [9]. The terms come from Gemba Kaizen, which means “Continuous Improvement” (CI).

Within the organisation in this research, a Kaizen event is a team-based continuous improvement process to be used at any time to focus the effort of a team when needed to drive improvement or creation of a process. The organisation suggests Kaizen as the mindset of continuous improvement and the belief that one can always do better. It utilises tools to quickly eliminate *Muda* (waste) and standardise the resulting process at *Gemba* (where the work is done).

The concept of Kaizen has been reviewed and mentioned in several literatures. Similarities between the philosophy behind Kaizen and TRIZ have also been identified. Womack and Jones referred to Kaizen as a lean thinking and lay out a systematic approach to help organisations systematically to reduce waste [10]. They described waste as any human activity that absorbs resources but creates or adds no value to the process [10]. Most employees could identify several different types of *Muda* in their workplace, but unfortunately the waste that they identify is only the tip of the iceberg. The authors stated that until these employees have been taught the essentials of lean thinking, they are unable to perceive the waste present in their environment [10]. TRIZ philosophy of ideality is very much aligned with this principle. Similarities between TRIZ, TOC (Theory of Constraints) and Lean are well described by Martin [11] as well as Anosike and Lim [12]. Sojka and Lepšík proposed that lean is described as good for waste elimination and TRIZ enables creativity and foresight [6].

These literatures suggest that TRIZ can work well with Kaizen. However, the investigation described in this paper focuses on the merging of application and training at the same time. The exercise was an effort to embed a formalised training within a Kaizen event to demonstrate how TRIZ can be applied.

3 The use of a real problem

A real problem was used in the previous attempt to deploy TRIZ training in the organisation. The use of a real problem worked effectively as it helped with the initial buy-in from the engineers to participate [7]. Hence, the utilisation of a real problem was again replicated in this study.

The problem used for the Kaizen and TRIZ training was related to the intermittent time jump issue seen by the operator of the instrument in the field. This issue happens once or twice a year and seems to be happening after Daylight Saving Time (DST) and in the region of countries that are observing Daylight Saving Time (DST). Addressing

this issue is important because the performance of the instrument relies heavily on the accuracy of time keeping. The problem was a software-based issue.

4 TRIZ tools covered in the training

As the organisation has formally included TRIZ in their problem-solving tools repertoire, the management mandated that the formal training should include the following:

1. Functional Modelling (FM) and analysis
2. Cause-and-Effect (CE) analysis
3. Substance-Field (SF) analysis
4. Technical contradiction
5. Physical contradiction
6. Patterns of Evolution
7. Function-Oriented Search (FOS)

In addition to the prescribed tool sets by the training module of the organisation, the heuristic of Situational Analysis (SA) [13] was also introduced to help during the problem definition stages.

It can be proposed that there are two main categories of TRIZ tools in the training – those that assist with problem identification and those that assist with problem ideation.

5 Methodology

Action Research [14-17] was used in the investigation. This methodology was chosen as it allows the planning, implementation, and data collection processes to be conducted at the same time. It allowed the first author, who conducted the training to adjust the training procedures as needed. To minimise bias, the data analysis was carried out by the second author who is independent from the training and the organisation.

To evaluate the effectiveness of the training, two sets of surveys were conducted. Pre- and post-surveys were conducted prior to and after the Kaizen event. In the pre-event questionnaire, baseline information including the number of years of work experience was collected. In both pre- and post- questionnaires, participants were asked problem solving self-efficacy questions. While the data was self-reported, in her study, Gadd found that self-perception of creative self-efficacy is a useful measure for training evaluation [2]. In his theory of self-efficacy, Bandura [18] proposed that it is a set of beliefs that allows a person to perform in a particular situation. Harlim suggested that self-efficacy is one of the factors that impact problem solving performance [19]. Therefore, the use of self-efficacy measurement is appropriate for the evaluation of the training. A set of problem solving self-efficacy questions developed by Belski [20, 21] were utilised. Participants were asked to rate the degree of their agreement to the following

5 questions using a 5-point Likert-scale (1 – Strongly disagree, 2 – Disagree, 3 – Neither disagree or agree, 4 – Agree and 5 – Strongly agree):

1. I am very good at problem solving
2. I am never intimidated by unknown problems
3. I am unable to tackle unfamiliar tasks
4. So far, I have been able to resolve every problem I faced
5. I am certain that I am able to resolve any problem I will face

In addition to the quantitative questions, qualitative questions were also included in the survey. This was because the number of participants in the study was limited by the number of engineers who were involved in the Kaizen event. A focus on qualitative data can yield in a richer in-depth analysis which are suitable for smaller sample sizes [16-18]. This qualitative question was included in the pre- and post-surveys:

- Do you expect that the way you approach problems may change as a result of this exercise? How do you think it might change or not change?

Additional qualitative questions were included in the post-survey:

- What you think was done well in the training/ Kaizen?
- What do you think can be improved in the training/ Kaizen?
- Do you think the exercise has helped you to understand how TRIZ tools can be applied to a real problem? If yes, how so. If not, why not.
- Do you think you will be more interested to learn more about TRIZ tools? If yes, why? If not, why?

In the post-survey, participants were also asked to rate the 8 tools that were used during the training in terms of their most-liked (1) and least liked (8).

The Kaizen and training were conducted over 6 half days (5 hours with 1 hour break) with the last day dedicated for report out. The training modules ran for half hour to one hour followed by team activities and discussions. On the first day, the training covered introduction and Functional Model (FM). On the second day, the training covered Cause and Effect Analysis and Trimming technique. On the third day, it was initially planned for Function Oriented Search (FOS), but the trainer decided to introduce Patterns of Evolution instead. On fourth day, Substance-Field (SF) analysis was covered followed by Technical Contradictions. On the fifth day, Physical Contradictions and FOS were covered. On the last day, the team analysed and ranked the ideas based on the number of efforts, project duration, complexity of the changes and technical risk. The ideas were then sorted with the lowest number of low scores being the top idea for easy implementation and simple changes and low technical risk. Prior to Kaizen and training, the participants completed pre-work on the initial CEA, FM and investigations summary. All the participants were briefed about the problem in the same way. SA was

used several times within the different training days, especially to bring about consensus on the problem identification process.

15 engineers took part in the training. 10 were male and 5 were female. The participants were from diverse domain technical knowledge and department (electronics, mechanical, software, system, science, field support, verification). Using the classification of expertise used by Harlim and Belski [22], out of those who participated in the training included 3 novice engineers (under 5 years of work experience), 3 mid-level engineers (5-10 years) and 8 engineers are expert levels (more than 10 years). 1 engineer opted not to answer the question related to work experience. Two of the engineers did not complete the post-survey. Therefore, for the purpose of this study only 13 responses were included for analysis.

6 Results & Discussion

6.1 Changes in perception of self-efficacy in problem solving

Table 1 presents the change in the perception of self-efficacy in problem solving by the engineers in the study. For questions 1, 4 and 5, the mean ratings of their problem-solving self-efficacy were reduced compared to their evaluation in the pre-survey. However, for questions 2 and 3, the mean ratings indicate that their confidence towards unknown and unfamiliar problem increased after the training. No statistical significance was observed when the data was tested with the Wilcoxon signed rank test ($p > 0.05$).

Table 1. Changes in perception of self-efficacy in problem solving

No.	Questions	PRE	POST
1	I am very good at problem solving	3.92	3.69
2	I am never intimidated by unknown problems	3.69	3.92
3	I am unable to tackle unfamiliar tasks	2.38	2.00
4	So far, I have been able to resolve every problem I faced	3.31	3.08
5	I am certain that I am able to resolve any problem I will face.	3.46	3.31

N=13, Wilcoxon signed rank test $p > 0.05$

The reduced mean rating in questions 1, 4 and 5 could indicate that after the training, participants may have a better understanding of their ability to solve problems hence, correcting their perception of problem-solving efficacy. Bandura suggested four ways of developing self-efficacy: 1) Mastery experiences; 2) Social modelling; 3) Social persuasion and; 4) Psychological responses [18]. Out of the 4, Bandura suggested that mastery experience or previous performance experiences is the most accurate [18]. The self-efficacy questions proposed by Belski [20, 21] covers two of the four sources of self-efficacy. Questions 1, 4 and 5 are questions based on mastery experiences, while Questions, 2 and 3 covers psychological responses. It is suggested through the experience of working with a real problem during the Kaizen event, participants were given

a chance to evaluate their own problem-solving performances. This allowed them to develop a more accurate problem-solving self-efficacy. It can be suggested that the increase in confidence mean ratings in Questions 2 and 3 support this.

This can also be further supported by the responses of the participants when asked *Do you expect that the way you approach problems may change as a result of this exercise? If yes, how did it change? If no, why do you think not?* All the participants believed that the exercise had a positive impact on the way they approach problems. Some of these responses are exemplified in **Table 2** below.

Table 2. Examples of responses to “Do you expect that the way you approach problems may change as a result of this exercise? If yes, how did it change? If no, why do you think not?”

Responses
“Yes, I will approach the issues and the problems with a different mindset.” (Participant 2, Male, Mid-level)
“Yes. It's opened my mind to more possibilities for a start. And also given me a toolset to draw from in a methodical way.” (Participant 3, Male, Expert)
“TRIZ is a structured way of approaching a problem, rather than going by the gut feeling. It also helps me keep an open mind to think in the uncharted territory.” (Participant 5, Male, Unknown)
“Yes, I think going forward when presented with a problem I will be more inclined to go back to the basic principle of TRIZ about trying to overcome psychological inertia. In a more practical sense, now having used all these TRIZ tools, I am more equipped to approach problems in new and different ways... I am also more confident that if presented with a problem I do not have a strong background in that I can still think through the problem in a way that I can suggest solutions.” (Participant 10, Female, Novice)

6.2 Things that worked well in the training, areas for improvements and further interest in TRIZ

Table 3 shows samples of participants' responses in the qualitative post-event evaluation. The general feedbacks indicate that the use of real problem, embedding the training within the Kaizen event, group work and the use of online platform worked well. In identifying areas for improvements, the participants suggested group participation can be improved, more Gemba and topics related to the 40 inventive principles can be explained better. Technological challenges such as internet connection was also raised.

The responses show that the training within the Kaizen event was well-received. The findings support the literatures reviewed by Sojka and Lepšik that TRIZ and Kaizen are compatible [6]. In addition, these data suggest there may be benefits in embedding the training in a Kaizen event. The use of a real problem offered opportunity for the engineers involved to apply TRIZ as they learned it. This may assist in overcoming the

barrier of uptake highlighted by Gadd [2] and other barriers of TRIZ uptake due to time and complexity as suggested by Ilevbarre et. al. [5] as well as Sojka and Lepšik [6]. The responses received from the participants indicate further interest in learning more about TRIZ.

Table 3. Examples of responses to the additional post-survey questions

Questions	Responses
What you think was done well in the training/ Kaizen?	<p>“Splitting into teams and carrying through the exercises as a team, hearing different opinions. Not shooting down ideas was great and created a safe environment.” (Participant 3, Male, Expert)</p> <p>“Defining question and making sure everyone on same page. Also training on concept and group exercises to apply the concept/tool on current problem was really good approach.” (Participant 6, Male, Mid-level)</p>
What do you think can be improved in the training/ Kaizen?	<p>“Pre-session deep diving into the data, looking at actual data, not hearsay from others. Looking at it together. Going to the Gemba.” (Participant 3, Male, Expert)</p> <p>“This was the first time this training was being done, and it was also online so there were issues because of that. Especially around team participation.” (Participant 5, Male, Unknown)</p> <p>“I think better definitions and examples of the 40 inventive principles would be really helpful to decrease time to proficiency of the tool.” (Participant 8, Male, Novice)</p>
Do you think the exercise has helped you to understand how TRIZ tools can be applied to a real problem? If yes, how so. If not, why not.	<p>“Yes, during this training/Kaizen, learning the new tools and practicing it in parallel with real problems showed the tools are helpful.” (Participant 7, Male, Expert)</p> <p>“I definitely see the utility for TRIZ tools. While they are flexible to applied to many situations the time involved to consider and implement them for a problem means they are likely best suited to events like Kaizens where an issue warrants great discussion and potentially has several unknown solutions which will deliver a great impact to key stakeholders.” (Participant 2, Male, Mid-level)</p>
Do you think you will be more interested to learn more about TRIZ tools? If yes, why? If not, why?	<p>“Yes, I would like to learn about practicing TRIZ in non-engineering problems and also in ideation. Standard work to run a slimmed down model of TRIZ would also be great and easier to sell to the business.” (Participant 8, Male, Novice)</p> <p>“Yes but also would like to practice using what we already learnt more too. Why - it is obvious to me that these tools would be quite useful for other problems/research/ideation. Given my background in research and systems and NPI engineering, I think back to all the design and development work where I can see that these tools would have been incredibly useful.” (Participant 10, Female, Novice)</p>

Participants mentioned that they would like more Gemba. The Japanese term Gemba refers to “where the action takes place”. For this problem, more Gemba would relate to more opportunities for the use of the software on the actual instrument. Unfortunately, this could not be done easily due to the constraints with online interaction and social distancing rules when this training took place. This highlights one of the limitations of an online-based training. Participants also suggested that the information related to 40 Inventive Principles can be better conveyed. This was also reflected in the data presented in the next section.

6.3 Rating of usefulness of the tools presented

Instead of looking at the rating of all 8 tools, only the tools rated 1 – most-liked and 8 – least-liked were considered for the purpose of this paper. **Table 4** presents the comparison of the responses of the 13 participants and **Table 5** are examples of some of the reasoning for the choices. Out of 13 participants, 12 participants rated tools that fall under the category of tools for problem identification as most-liked. Participant 3 who rated Technical Contradiction, a tool that falls under ideation (40 Inventive Principles) explained his reasoning as:

“I felt the contradictions together were most relatable to thinking patterns I already had used before. This made them simpler to understand, build upon and enjoy the process of using them more as a result.” (Participant 3, Male Expert)

Out of 13 participants, 12 participants rated tools related to ideation as least-liked. Participant 2 who rated Su-Field as least liked indicated that his reasoning was because he was not present during the session. Interestingly, looking at the tool that he had rated 7, it was Physical Contradiction which also fell under the category of ideation tools.

The data indicates that there was a preference for tools that help in problem identification. During the training, it was also observed by the trainer that some of the TRIZ tools were less effective than the others for the specific problem presented in the training. The preference for FM as shown in the data may be because the problem was software specific. On the other hand, in general, participants perceived tools that are focused on ideation to be least liked as they were difficult to comprehend. It is acknowledged that TRIZ can be complicated and challenging to teach or train people in [5, 6]. This study identified specific tools of TRIZ that are perceived to be more challenging for learners new to TRIZ to uptake. In the data, the one participant who liked the Technical Contradiction module indicated that his past experiences made it easier to understand. This supports that prior experience has an impact on understanding more complex principles in TRIZ and should be taken into consideration when designing TRIZ trainings.

Table 4. Rating of the tools presented most-liked vs least-liked

Participant No.	Gender	Expertise Level	Most-Liked (Rated 1)	Least-Liked (Rated 8)
1	Male	Expert	FM	Technical contradiction
2	Male	Mid-level	FM	Su-Field
3	Male	Expert	Technical contradiction	FOS
4	Male	Expert	FM	FOS
5	Male	Unknown	SA	Patterns of Evolution
6	Male	Novice	FM	Technical contradiction
7	Male	Expert	CEA	FOS
8	Male	Novice	FM	FOS
9	Female	Expert	FM	FOS
10	Female	Novice	FM	Physical contradiction
11	Female	Expert	FM	Physical contradiction
12	Male	Expert	FM	Physical contradiction
13	Male	Expert	FM	FOS

Table 5. Examples of reasonings given by the participants for the ratings of the tools.

Questions	Responses
Why did you select the top module as the most-liked compared to the rest?	<p>“In my opinion situational analysis is the most practical of all the tools. It asks important questions on what is wrong with the situation, helps us to scope the problem by defining what system we are looking at, identifying what is the actual MUF so that we open our mindset to more possibilities for changes, helps us to think about how we measure success and to consider user and system needs. It reminds me of the traditional system V model in design and development.”</p> <p>(Participant 10, Female, Novice)</p> <p>“It helps to decompose a system (framework) into cubes and make it possible to explore the interaction among cubes.”</p> <p>(Participant 9, Female, Expert)</p>
Why did you select the bottom module as the least-liked compared to the rest?	<p>“Requires time to get used to the tools, especially the relating the 40 principles to the problems at hand.”</p> <p>(Participant 6, Male, Novice)</p> <p>“Still do not fully understand the application of these concepts.”</p> <p>(Participant 12, Male, Expert)</p>

7 Implications, Research Limitation and Future Research Direction

The results in this study have implications for organisations wanting to develop or implement in-house TRIZ training. It also has implications for global organisations considering TRIZ training remotely via online conferencing tools to cater to their workforce who may be located in multiple sites.

Overall, this research shows that the embedding of TRIZ training within an online Kaizen session worked well and can be effective. The use of a real problem and the merging of training with the Kaizen session, allowed participants to learn and apply TRIZ at the same time. The training allowed participants to develop a more accurate problem-solving efficacy, boosting their confidence for unfamiliar and unknown problems. The investigation also identifies which TRIZ tools posed challenges for deploying effective training such as tools that are commonly used for ideation: FOS, Patterns of Evolution and tools related to the 40 Inventive Principles. The findings suggest that when designing training around these tools, proper consideration of the participants' previous experiences may also need to be considered, on top of the overall training design.

One of the key limitations of this study was the number of participants which was constrained by the engineers in the organisation who were involved in the Kaizen session. However, the research design had taken this into account and included qualitative data collection on top of quantitative ones. The qualitative responses allowed for an in-depth data with the smaller sample. The use of a real problem was beneficial, but it also meant that the practice of application of TRIZ was limited to that one problem during the training. Future research could focus on the expansion the training within other Kaizen sessions in the organisation, increasing the different types of problems to apply on during the training as well as improving data collection with more participants. An investigation on how to design more effective training around some of the ideation tools which were identified as complex can also be carried out.

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