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On the effectiveness of TRIZ tools for problem finding

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Abstract

The ability to understand problems well, often referred as problem finding, is identified as the most important aspect of engineering problem solving. The use of some ideation tools can assist in this endeavor. The effective utilization of certain tools can even impact the long-term development of problem solving ability. This study investigates how different tools of TRIZ can be helpful for problem finding. This paper considers the following: 1) What functionality are required in a problem solving tool to ensure effective problem finding?; 2) Which tools of TRIZ can assist problem finding?; and 3) How does the use of these TRIZ tools enhance the process of problem finding? The tools explored in this paper are: Situation Analysis, Substance – Field Analysis, Method of the Ideal Result, ARIZ, OTSM and IDM-TRIZ. Discussions are also made as to why these tools of TRIZ offer benefit for problem finding. The results from this paper have implications on the design of training programs in TRIZ for both educational and professional settings.

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Keywords: Engineering creativity; fixation; memory search; Substance-Field analysis; Method of the Ideal Result.

1. Introduction

The focus of engineering education is the development of engineers' ability to solve problems [1, 2].This is one of the unique aspects of engineering education as it increases the opportunity for a wider career pathway for engineering graduates. Beder even suggested that some engineers are able to easily cross into other professions specifically because of their problem solving ability [1]. Therefore, it is imperative to investigate how problem solving performance can be enhanced through formal instructions. It has been reported that learning TRIZ increases self-efficacy which is vital for the long-term development of problem solving ability [3, 4]. A comparison of students' feedback on a TRIZ unit and other engineering units that was deployed at RMIT University between 2006 and 2010 was carried out. It was found that learning TRIZ developed students' problem solving ability significantly more than all the units incorporated into four years of engineering degree added together [5]. From these, we conclude that learning tools of TRIZ benefit

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the development of problem solving skills. This paper is a continuation of our previous work on the investigation of how ideation methodologies can assist in the development of problem solving skills of young engineers.

It has been reported that in order to resolve problems effectively, the problem solver needs to carry out problem finding [4, 6, 7]. While TRIZ is well-known for its sound problem solving tools that help to develop creative solutions, Ikovenko suggested that traditional TRIZ tools are not effective in formulating a problem statement and in conducting adequate problem analysis [cited in 8]. The on-going evolution of TRIZ tools has catered for this by reshaping TRIZ from being solely focused on solution-generation to a comprehensive set of problem solving tools that also facilitate reliable situation analysis. It is important to explore current tools of TRIZ that can assist in problem finding which can be included as part of the training of engineers. This paper explores and considers the following:

1) What functionality are required in a problem solving tool to ensure effective problem finding?
2) Which specific tools of TRIZ can assist problem finding?
3) How does the use of these specific TRIZ tools enhance the process of problem finding?

2. Engineering problem solving and problem finding

2.1. Engineering problem solving

Most of engineering problems faced by university students are well-defined and usually have a single correct answer. The research by Jonassen, Strobel and Lee [9] and Beder [1] identified that problems faced by engineers in the real workplace differ significantly from those presented in a university setting. It was found that the problems faced by engineers in industry are often ill-structured and seldom have a single correct solution [9, 10].

Ill-defined problems are characterized by the following [11]:

1) Not all the problem parameters are known.
2) The problem can be interpreted in many possible ways.
3) Interdisciplinary knowledge is required to resolve the problem.
4) Possible solution/s may impact other parts of the system being considered.
5) The problem can be resolved by many solution paths.

2.2. The importance of problem finding

Current problem solving theories and literature suggest that problem solving requires a number of specific skills and is conducted via a number of steps. Typically, good problem solvers are expected to be able to (i) identify a problem, (ii) plan and (iii) execute a solution, and then (iv) evaluate the solution [12-15]. The expectation is that good problem solvers must be able to carry out all four specific steps efficiently [13, 16]. Mayer suggested that the process of resolving problems requires two processes: problem definition and problem solutions [6]. These two processes are particularly important when facing ill-defined problems. As previously established, the problems faced by engineers are often ill-defined. Therefore, engineers should be able to define the problem first prior to finding the solutions. This was reflected in our own research into the factors that impact on the problem solving performance of engineers. Our study revealed that the most crucial aspect for effective problem solving lies in the ability to understand the problem well such that the correct problem is considered [4]. We propose that the process of problem definition and understanding the problem can be referred to as problem finding. Runco and Dow believed that problem finding is the precedence step prior to problem solving and includes the following processes: "problem discovery, problem construction, problem expression, problem posing, problem definition, and problem identification" [7, p. 433].

Other research also highlighted the importance of problem finding. Sobek II and Jain found strong relationships between client satisfaction, which they used as a measure of a "good" problem solving outcome, and activities related to problem definition [17]. Litzinger et al. also suggested that problem solving errors are usually a result of poorly analyzed problems [18]. The research of Chi and Glaser supported that understanding the problem is very important, especially when resolving complex problems [19].

This finding also accords with the concept of problem space in the theory of human problem solving posited by Newell and Simon. They argued that "when a problem is first presented, it must be recognized and understood" [20,

p. 809]. They also believed that during the establishment of the problem space, problem solving occurs naturally and acceptable solutions can be obtained [20].

Thus, it can be proposed that tools that assist with problem analysis can enable a problem solver to resolve problems more effectively and that it is vital for engineers to learn tools for problem analysis/representation.

2.3. Criteria for effective problem finding

As previously established, real-life engineering problems are ill-defined and are also complex [9, 11]. Typically such problems accommodate many interacting systems and contain numerous variables. Simon proposed that the process of decomposition is required when resolving ill-defined problems [21]. In problem decomposition, a complex problem is broken down into manageable parts in order to resolve it [21]. Liikkanen and Perttula suggested that decomposition is important in assisting problem restructuring [22]. Therefore, we believe that effective problem solving tools should assist the problem solver in the process of decomposition.

As previously stated in section 2.1, ill-defined problems can be interpreted in many ways. Therefore, prior to any problem solving to be undertaken, a problem solver needs to define the problem. Schon suggested: "In order to formulate a design problem to be solved, the designer must ***frame*** a problematic design situation: set its boundaries, select particular things and relations for attention, and impose on the situation a coherence that guides subsequent moves." [23, p. 182]

Carlson and Bloom found that the process of problem solving occurs in a cyclic manner [14]. Cross also highlighted the cyclic process of problem solving [24]. Citing past studies on design expertise, he proposed that experts use quick solution conjectures to re-frame problems [24]. These quick solution conjectures assist problem solvers in understanding problems better. We have also observed similar expert behaviors [25].

Our research findings have identified that a problem solver's interpretation of the world significantly influences his or her understanding of the problem [4]. This finding is supported by the work of Carlson and Bloom, who observed that expert decisions were affected by beliefs about mathematical concepts [14]. In reiterating the link between problem solving and thinking, de Bono emphasized that thinking has everything to do with perception [26]. He argued that "perception is the most important part of thinking" [26, p. 15]. Wilson [27] and van Gelder [28] also supported the idea that perception affects thinking skills. Perkins [cited in 26] found that errors in thinking are usually caused by errors in perception.

For this reason, open-mindedness is required for effective problem finding. The value of open-mindedness for problem solving was raised in our research as well as that of Adams [29, 30]. In addition to open-mindedness, our research also discovered that effective problem finding requires a problem solver to be engaged in evaluation and reflection [25].

Based on the literature and our own findings, we propose that effective problem solving tools should cater for the following:

1. Assist in the process of decomposition:
    a. By breaking down a complex problem into manageable elements.
    b. Facilitating the clarification of problem structure/s.
2. Assist to see the problem from different angles:
    a. Increasing the consideration of problems from different perspectives.
    b. Taking into account the need of open-mindedness.
3. Accommodate the cyclic nature of problem solving (re-framing):
    a. Through the use of quick solution conjectures.
    b. Through continuous re-evaluation and reflection.

3. TRIZ Tools Suitable for Problem Finding

3.1. Tools Taught at RMIT University

3.1.1. Situational Analysis

TRIZ provides problem solvers with a set of tools for problem solving. Specific to problem finding, Situation Analysis (SA) can be a very useful tool for engineers. SA is one of the TRIZ tools that are taught to students in RMIT University's TRIZ unit (For more information on the TRIZ unit at RMIT, see [3, 5, 31]. While conducting SA students are required to answer a set of 11 questions. These questions require students to evaluate and reflect on their own assumptions on their interpretation of the problem. We believe that SA addresses some of the requirements of effective problem solving tools as identified in section 2.3. With a focus on problem finding, SA assists in the process of decomposition and helps with re-evaluation as well as with reflection. SA also forces the user to consider different aspects of the problem including other parts of the system as well as human factors that are usually present in every factual engineering problem.

Even though the questionnaire is comprehensive, the benefit of SA is that it can be easily deployed and taught to engineers. In the TRIZ unit at RMIT University, students are firstly taught on the use of SA prior to teaching them other tools of TRIZ. Over 90% of students surveyed on the effectiveness of different TRIZ tools taught at RMIT University believed that SA is beneficial for their problem solving [32]. Therefore, we recommend that SA should be included in any TRIZ training for young engineers.

3.1.2. Substance-Field Analysis

Students at RMIT University are also taught to use Substance-Field (Su-Field) Analysis [33]. Su-Field Analysis models any natural and man-made system as a set of interacting elements. The system is presented as a set of substances interacting with each other by means of fields, which are generated by the substances. This tool incorporates both problem representation and a search-based problem solving heuristic. Su-Field presents problems graphically using circles and arrows [33]. The use of graphical representations in problem finding can be useful for the problem solver. Feedback from students confirm this [30]. The use of Su-Field also enabled students to break down a complex problem into smaller manageable problems. Students are initially asked to model the interactions of the different substances and fields. They are then taught to break the problems into smaller conflict triads and to consider each triad separately [33]. In terms of problem finding, Su-Field assists problem representation and decomposition.

3.1.3. Method of the Ideal Result

Another tool of TRIZ that is included in the TRIZ Unit at RMIT University is Method of the Ideal Results (MIR). MIR is developed based on the TRIZ notion of the Ideal Ultimate Result (IUR) by Belski [15, 34, 35]. MIR assist the problem solver to focus on the most important part of the problem and also to consider existing resources that may be used to resolve the problem. Similar to Su-Field, MIR is a tool that can be used to analyze problems as well as come up with possible solutions. MIR combines both graphical and text representation of a problem and its causes. The use of MIR also requires the user to evaluate their target task and the solution hence, accommodating the cyclic process of problem solving.

3.2. Other TRIZ Tools That Can Assist Problem Finding

3.2.1. ARIZ

ARIZ is a Russian acronym for "The Algorithm for Inventive Problem Solving". ARIZ comprises a set of systematic steps for resolving problems that seem impossible to resolve (non-typical problems). Therefore, the use of ARIZ is suitable for defining ill-defined problems. Since the start of its development in 1956, ARIZ contains numerous steps specifically devoted to situation appraisal [36, p. 196]. It also takes into account the use of quick solution conjectures and re-evaluation. Thus, it assists problem reframing. Despite the benefit of ARIZ, it may be a challenge to teach young engineers with no knowledge of TRIZ the tool of ARIZ. This tool is complicated with the current version consisting of 9 sections with 40 steps [37]. Interestingly, Terninko, Zusman and Zlotin also found only 5% of all problem solvers apply ARIZ [cited in 37]. Even so, when deployed ARIZ can be a useful and effective problem solving tools for young engineers to learn as the use of ARIZ can result in innovative solutions [38].

3.2.2. OTSM-TRIZ Network of Problem

An alternative to ARIZ is OTSM. OTSM is the Russian acronym for "General Theory of Powerful Thinking" and is also developed to assist in resolving non-typical problems [39]. OTSM Network of Problem (NoP) focuses on problem finding. OTSM NoP allows the user to create a diagram that breaks down the problem into different parts. It also allows consideration of possible solutions (partial solutions). The value of OTSM is that it allows for quick solution conjectures to be considered and it also focuses on problem re-framing through the cyclic process. This tool also allows the consideration of new problems that may arise due to the introduction of the partial solution. This tool also assists with the evaluation aspect that is required for effective problem finding. In their comparison on the use of ARIZ and OTSM-TRIZ, Fiorineschi, Frillici and Risonne found that OTSM-TRIZ offers better usage for complex problems [40].

3.2.3. IDM-TRIZ

IDM-TRIZ is acronym for Inventive Design Method which was developed at INSA Strasbourg. It provides a complete set of steps from problem formulation to solution concepts [41, 42]. Within IDM, graphical representation of problems is used and assists with decomposition. The problem is considered from different perspectives in IDM. The usage of IDM allows team input, including explicit and tacit knowledge of experts involved in the problem solving. This allows for the consideration of the problem from different perspectives. Solutions concepts and evaluation of the cause and effect of partial solution are also in-built into this tool, making it suitable for problem finding.

4. Conclusion & future research

Problem solving requires two main processes: 1) problem finding and 2) problem solving. This paper discusses the importance of problem finding and the opportunities that TRIZ tools can offer for educating engineers in problem finding. With the many tools within TRIZ, this paper attempted to select and discuss some of the tools that may be suitable for problem finding. Situation Analysis, Substance-Field Analysis, Method of the Ideal Result, ARIZ, OTSM and IDM-TRIZ covers the criteria of effective tools for problem finding that was established in this paper. The recommendations made in this paper have implication for the design of effective training programs in problem solving for engineers.

The limitation of this paper is that it only provides a snapshot of suitable tools to teach to young engineers for effective problem finding. While recommendations are made, further investigations in experimental settings are still required. Future research can be focused on a standardized evaluation of courses that implement different types of TRIZ tools mentioned in this paper. An investigation on the type of course structure or how the different tools can be combined should also be carried out.

Despite its limitation, the discussions offered in this paper can assist in better development of TRIZ training for engineers, both in the educational and professional settings.

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