Teaching TRIZ Problem-Solving Methodology in Higher Education: A Review

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Abstract: ***TRIZ was invented in the former USSR in 1946 by Genrich Altshuller with his colleagues, and its main purpose at that time was to assist engineers to invent new products in a more efficient manner as oppose to the normal trial and error methodology. TRIZ is a Russian words and it means "Theory of Inventive Problem Solving" or TIPS. It was introduced based on the belief that there are universal principles of invention that are the foundation for creative innovations that help in creating and advancing technology. Even though TRIZ was initially developed to solve inventive problems in engineering-related problem domains, nowadays it has gained popularity in other fields such as in education, business, and other non-technology or non-scientific fields and domains. Several studies have been carried out in the past to investigate and analyze the benefits of teaching TRIZ to students at tertiary or higher level of education, and the results were very encouraging. In this paper, a review of several applications of TRIZ in higher education is performed, and based on the results of the review; a short summary of the findings is presented.***

Keywords: Higher Education, Inventive Problem Solving, Structured Methodology, TRIZ Methodology.

1. Introduction

Institutions of higher learning are places where students learn how to solve various types of problems, ranging from straightforward problems that can be solved easily and complex problems that usually involve critical thinking. Most of the problems must be solved in a given amount of time, which is normally quite short. If the problem is quite simple and has been experienced before, then the time taken to solve it will not be an issue.

But, solving complex problems such as inventive problems that require creative and critical thinking will be quite time-consuming if the trial and error methodology is applied. It may take several years for an inventor to come up with a new invention, and nowadays things are moving really fast. New products and inventions can become obsolete within less than one year, and the life span of each product is getting shorter with the availability of all kinds of tools in the market.

All of us face all kinds of problems in our everyday lives, especially at work. So, what is a problem? By definition, a problem is any difficulty, obstacle or issue that needs to be analyzed and overcome using factual knowledge when solving the problem. On the other hand, problem solving is a cognitive or mental process where an individual or a group of people is required to identify the precise problem and find the solution to the problem, and it is part of a larger problem process [1]. Whenever a person or a group of people faces an undesirable situation, problem-solving activity is required in order to correct the unwanted situation.

When solving a problem, most people follow a sequence of general steps, and most of the time, some steps must be done repetitively or in cycle until a satisfactory result is achieved. As the complexity of a problem increases, a more systematic methodology to problem solving is required in order to ensure that the solution solves the current problem satisfactorily.

The following is a list of steps that is commonly used in solving problems systematically [2]:

- Identifying the problem
- Defining the problem
- Determining the best strategy that suits the problem
- Organizing and gathering facts and knowledge regarding the current problem
- Allocating all resources (time, money, people, etc.)
- Monitoring the progress
- Evaluating the results

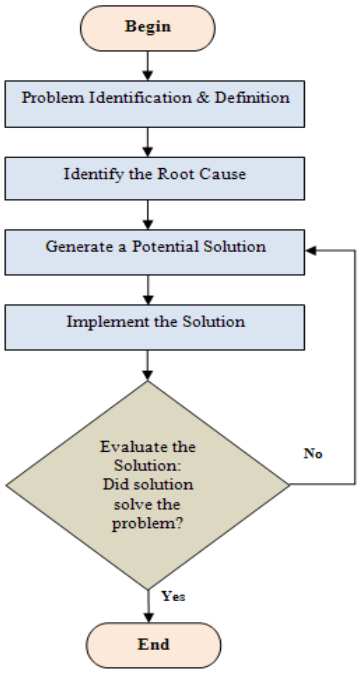

Figure 1: Structured problem-solving methodology [3], [4]

Currently, most students in institutions of higher learning use the structured problem-solving methodology in solving problems assigned to them. Fig. 1 [3], [4] presents the steps

that normally occur when using the structured methodology. In this illustration, it is assumed that some steps are performed repetitively until the problem's solution meets the requirements or standards, and the loop terminates upon reaching an acceptable solution.

The structured methodology to problem solving is quite similar to any other problem solving methodologies because the main goal is to find the most suitable solution to the current problem in a systematic manner. But when solving inventive problems, the structured methodology has to be combined with other methodologies such as TRIZ, brainstorming, Six Sigma, etc. so that the problems can be solved efficiently and effectively. Furthermore, thinking outside the box is required when solving inventive problems.

2. Research Objectives

The main objective of this research is to conduct a review on the use of TRIZ in higher education such as at universities, colleges, academies, etc. Several significant applications of TRIZ in tertiary education are highlighted and described in more detail to show how the concepts in TRIZ can benefit students in solving problems. A summary of the findings of using TRIZ problem-solving methodology in assisting students to enhance their problem-solving ability and skills is presented.

3. What is TRIZ?

TRIZ is a Russian word that stands for "Theory of Inventive Problem Solving" or TIPS, which is the equivalent phrase for TRIZ in Russian [5]. TRIZ was developed in 1946 by Genrich Altshuller and his colleagues in the former USSR, and it is now being used widely throughout the world in solving complex or inventive problems [6], [7], [8] in various fields and domains.

TRIZ was created based on the theory or belief that "there are universal principles of invention that are the basis for creative innovations that advance technology, and that if these principles could be identified and codified, they could be taught to people to make the process of invention more predictable [6]". Altshuller discovered that invention is nothing more than the removal of technical contradiction with the assistance of a set of known principles. He emphasized that one does not have to be born an inventor in order to be a good inventor, and he criticized the trial and error method that are normally used to make discoveries [9].

The main rule is that the progress and evolution of technological systems is governed by a set of objective laws, which Altshuller called Laws of Technological System Evolution [3], [7]. To devise these laws, Altshuller originally started by analyzing around 200,000 patterns and invention descriptions from various fields of engineering from available world-wide patent databases. Altshuller also made a conclusion that there were around 1,500 technical contradictions that could be solved easily by simply applying the discovered principles [9].

Innovation involves *continuous improvements* to existing designs and processes. TRIZ is a systematic approach for finding advanced and creative solutions to difficult problems in a more efficient and effective manner to ensure that the solutions are up-to-date and still relevant during its launching.

A general framework of TRIZ problem-solving methodology is presented in Fig. 2 below [7]:

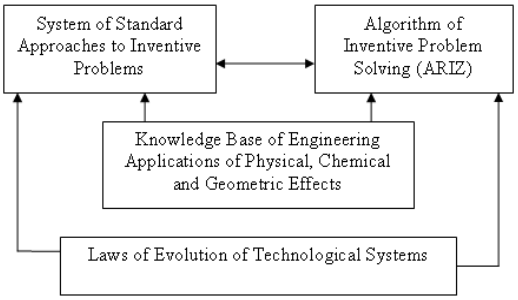

Figure 2: TRIZ problem-solving methodology [7]

Based on Fig. 2, the four components must work together in order to solve the problem use several tools as illustrated in Figure 3.

Fig. 3 [3], [4], [10] shows the tools along with the principles that are used in solving a given problem using TRIZ. From the diagram, it can be concluded that TRIZ's way of solving problem is quite simple and direct to the point. A specific problem is first generalized to become a general problem; then a model of solution to the generalized problem is derived using all the laws and principles within TRIZ; finally, the model of solution is used to derive a specific solution to the actual specific problem.

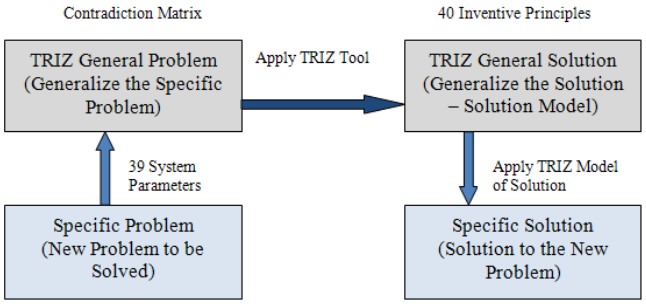

Figure 3: Schema of solution of problems using TRIZ [3], [4], [10]

Further details on TRIZ and its applications can be found in [4].

4. A Review of Significant Past Research Works on TRIZ in Higher Education

In the past, TRIZ has been used in education systems with the main objective of increasing students' problem-solving ability and skills. There exist many significant applications of TRIZ in higher education, and a few of them are discussed in more detail in this study.

In a paper [11], at RMIT, a group of forty-two engineering students were enrolled in a course on TRIZ for duration of 13

weeks. It was discovered that most of the students were not aware of any other problem-solving methodology or tools before learning TRIZ problem-solving methodology. In other words, TRIZ was the only problem-solving methodology that was formally taught to them at their tertiary education.

As a result of this experiment, the students' perceptions of their capabilities in solving problems have changed extensively, and their thinking abilities have also changed (improved) in such a way that they were able to come up with better ideas that they would never thought of while doing their final project [11]. The experiment also revealed that the course on TRIZ tools has greater impact on students' problem-solving ability much more than the disciplines based courses [11]. The following list gives some of the most significant findings from this research of teaching TRIZ [11]:

- Improved the ability to attempt open-ended problems
- Improved the students' structured/systematic thinking
- Able to look beyond the current knowledge
- Changed in thinking style
- Acquired good problem-solving skills (after completing the course)

From the above results of teaching TRIZ to a group of engineering students, it can be concluded that TRIZ was able to improve the students overall problem-solving ability and also able to increase the students' level of self-confidence in handling and solving new problems.

In another paper, Nakagawa [12] reported his findings on his experiences of teaching under-graduate students and industrial engineers in using TRIZ problem-solving methodology along with USIT (Unified Structured Inventive Thinking) on how to think and solve problems creatively. USIT was developed by Sickafus [13] in 1995, and its creation was heavily influenced by TRIZ problem-solving methodology. Basically, USIT is a method that assists the problem solver in performing creative thinking process – practical process for thinking [14]. In USIT, two additional steps or processes are added to the original 'Four-Box Scheme' of TRIZ, and its diagram is termed the 'Six-Box Scheme'. Fig. 4 [12] illustrates USIT methodology [13].

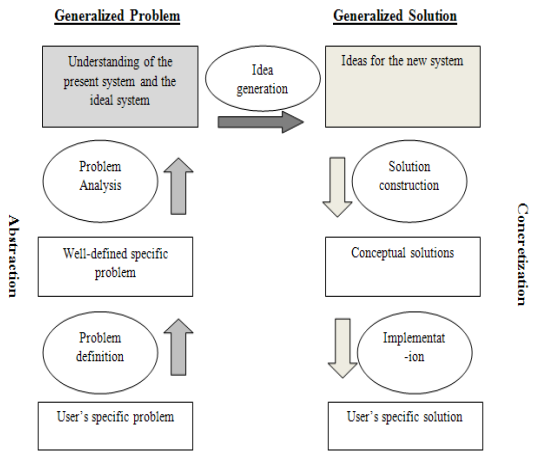

Figure 4: Six-Box scheme of creative problem solving in USIT [12]

USIT with TRIZ as the underlying concepts have been used in many presentations, seminars, and also applied in many research papers and are mainly addressed to engineers in industries. It was discovered that a short-term 2-day seminar was already good enough to train those engineers who were highly motivated and possessed some experiences with knowledge background in technologies and the simple structure of USIT [12].

On the other hand, it was also discovered that teaching university students on creative problem-solving with TRIZ and USIT required longer time period because most of the students had to first understand technologies in general terms and concepts. They had to know what systems, attributes, functions, processes, cause and effects, and also had to understand the physical/chemical mechanism behind the problems.

Other issues in teaching students TRIZ/USIT included the fact that they lacked experiences in technological development, manufacturing process, and patent reading/writing. All of these issues also made them feel unmotivated (no interest) in learning the methodologies for creative problem-solving thinking.

The most basic concept in TRIZ is that innovative and creativity ability in producing new inventions can be taught and there is no need for the inventors to spend so much time (several years in most cases) to come up with new inventions. With this idea in mind, the author in [15] introduced the concept of Innovation Education, which is considered as the cornerstone of national development. In this paper, the author aimed at finding ways of strengthening the Innovation Education. Here, the author introduced the TRIZ Theory in the Innovation Education, and the relationship between the Innovation Education and the TRIZ Theory was analyzed thoroughly. Each aspect within the Innovation Education has elements of TRIZ and this has overcome some issues or questions related to Innovation Education.

The Innovation Education's system as proposed in [15] is illustrated in Fig. 5. Innovative educational contents were introduced in this model. Briefly, the suggested "TRIZ System in Innovation Education" has the following components [15]:

- Education innovative method and problem analysis method
- Teaching and technical system evolution law
- Teaching and technical conflict solution principle
- Standard solution of question about teaching and technical innovation
- Solution algorithm of teaching and technical question
- The knowledge library of teaching

The solving method's components (as shown in Fig. 5) are the teaching question systematization, ideal solution scheme of teaching, and conflict solving of teaching and technical problem [15].

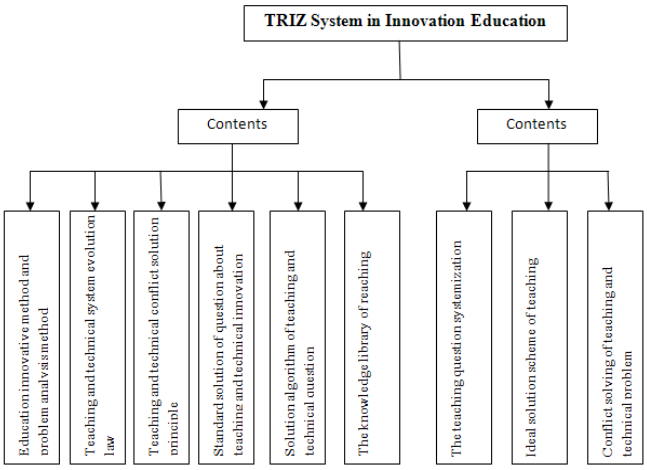

Figure 5: TRIZ system of Innovation Education [15]

The relationship of TRIZ Theory and Innovation Education was also modeled, and is shown in Fig. 6 [15]. The analysis done on the TRIZ Theory showed that it provided a suitable methodology for supporting the Innovation Education based on the following aspects:

- *Provides the support for the innovation education, innovation method and the analysis method*
- *Solve a variety of contradictions encountered in Innovation Education*

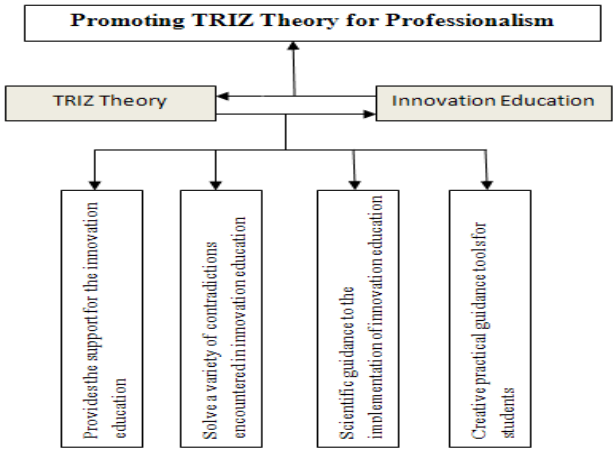

Figure 6: Relationship of the Innovation Education and TRIZ Theory [15]

Several other specific applications of TRIZ in Innovation Education such as in the curriculum design and innovation training were presented in [15] and they are useful as references to those who plan to implement Innovation Education with TRIZ problem-solving methodology [15]

In another work, the authors considered "possibilities of performance of new requirements into an education system" and its connection to the formation of a global innovative society. The potential of the innovative educational technologies that are created at this time are classified by levels depending on the degree of performance of the identified requirements [16].

Here, TRIZ-pedagogic consisting of the integration of studying of relevant teaching materials of various disciplines and subjects with studying of Theory of Inventive Problems Solving (TRIZ) was proposed.

The main goals of the modern TRIZ-pedagogic are to first develop the ability of trainees to consistently solve problematic tasks in their professional work and other activities, and also to solve other relevant problems using TRIZ. These goals can be achieved by TRIZ-pedagogic by integrating TRIZ with currently available teaching materials and methods of other disciplines and fields [16]. TRIZ pedagogic accomplishes these goals mainly by the integration of TRIZ with relevant teaching materials that are pre-determined by programs of other disciplines and subject.

Lepeshev et al. [17] studied the "development of creativity in engineering education using TRIZ", and in this paper Theory of Inventive Problem Solving was applied to creativity. TRIZ was applied intensively to creativity construction and development in engineering education, and the emphasis was in TRIZ's efficiency in producing innovative results. But, it was also discovered that more class periods were required for high quality studying of TRIZ. This issue (more class periods) was also overcome using a system of innovative education of TRIZ-pedagogics of integrating the studying or learning of TRIZ with other disciplines or subjects, which was similar to the research done in [16]. Here, the authors' method on knowledge invention, "in which any systems studied in different disciplines are 're-inventing' by means of TRIZ principles and standards as a result of overcoming of the contradictions in systems predecessors [17]" was described in very detail.

In another paper [18], the authors introduced the use of TRIZ to innovative ability training for mechanical engineering's major. Their main objective was to enhance the innovative capability of the mechanical engineering's students by first analyzing the development of Innovation Education in their country (China) and abroad; all problems in mechanical professional innovation ability's training of mechanical engineering students were also analyzed.

TRIZ Theory was proposed and introduced into the innovative training's of these mechanical engineering students and the TRIZ application model was established and being refined with regards to the provided specific aspects [18]. Analyses were also done on the influencing factors from thinking characteristics of students and school innovation environment to the application of TRIZ to the Innovation Education.

Fig. 7 illustrates the TRIZ application model introduced in [18].

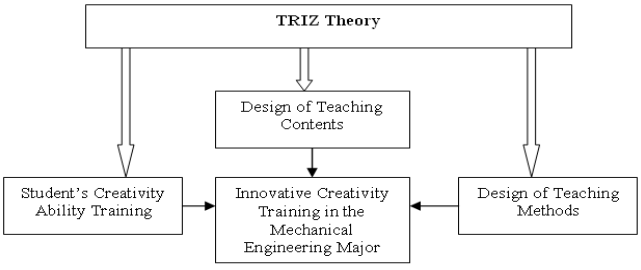

Figure 7: The application model of TRIZ Theory [18]

There are many other research papers that discussed and studied the use of TRIZ in education in improving the students' learning and problem-solving ability, which include [19], [20], [21]. In [19], the idea of applying TRIZ in remote engineering approach (e-learning) was introduced.

A study on the training pattern of undergraduate students' innovative ability using TRIZ was conducted and analyzed in [20], and the results also showed that the integration of the Innovation Education and TRIZ Theory managed "to expand the Innovation Education space and improved the college students' innovative thinking and ability [20]."

The *Butterfly Model* to problem solving, which was also based on TRIZ was introduced in [21], and it simplified the descriptions of complex problems, and hence simplified the problem-solving process. A right representation of the problem was the main contribution in structuring and handling contradictions, and this reduced the problem space.

5. Findings

TRIZ is normally used to solve engineering-related, technology-related, and scientific-related problems. In the past many applications in science and technology employed TRIZ in getting results effectively and efficiently with the assistance of the various proven steps used within TRIZ. TRIZ problem-solving methodology is famous for its ability to produce solutions to problems based on past related technologies and at the same time allows users to come up with innovative products really fast.

Nowadays, TRIZ is applied to solve various types of problems ranging from engineering-related or technology-related problems to problems that are not technology-related, including in higher education.

Based on the review perform on several significant applications of TRIZ in higher education, the following findings have been gathered:

- TRIZ is currently widely used to teach engineering students because of its close relationship with any engineering fields or disciplines. Furthermore, TRIZ was initially developed to handle problems within engineering systems.
- TRIZ is very relevant to be implemented as a tool in Innovation Education because of its effectiveness in solving complex problems.
- TRIZ's main rule that states that the progress and evolution of technological systems is governed by a set of objective laws is very applicable when dealing with technology innovation in education.
- In most applications of TRIZ in higher education, the TRIZ Theory was applied to the various teaching modules or contents and also to the existing teaching methods and techniques.
- TRIZ was used in various trainings and workshops with the main objective of developing and enhancing students' creativity ability and skills.
- Contradictions that occur during innovation can be overcome easily using TRIZ because TRIZ can be used to simplify the representation or the structure of the existing contradictions and problems, and hence can make the problem-solving activity more efficient. In TRIZ, a contradiction occurs when an improvement in one aspect of the product can cause another aspect to worsen or deteriorate.
- Appropriate knowledge library of teaching (contents and methods) must be made available if TRIZ is to be applied in any institutions of higher learning. This is the knowledge base component within TRIZ.
- A set of laws that are relevant to teaching and learning must also be produced because this is one of the most important components when using TRIZ in education.
- Inventive problem solving can be made easy by using TRIZ.

The above findings can be improved further if more applications of TRIZ in higher education in the various aspects and parts of education are reviewed.

6. Future Work and Conclusion

Future work include introducing a conceptual model for an improved education system that integrates TRIZ with the conventional education systems and also to make the Innovation Education concept more appealing to students in general regardless of whether they are studying technology-related courses or non-technology-related courses.

Students in higher education must be taught to solve inventive problems efficiently and effectively. When TRIZ was first introduced, it was meant to be used to solve engineering-related problems, and in the past many applications employed TRIZ in getting results effectively and efficiently in many different domains.

It has been established that TRIZ problem-solving methodology is known for its ability to solve problems based on past related technologies, and also allows users to produce innovative products efficiently and effectively. With this in mind, teaching TRIZ to university and college students is something that must be considered by the administration of each institution of higher learning in ensuring that students are able to solve inventive problems (IP) easily.

It can be concluded that TRIZ has become one of the most important problem-solving methodologies that has a great impact in enhancing inventive problem-solving's ability and skills of students in higher education.

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