Abstract

The didactic opportunities of TRIZ allow the concept of the TRIZ evolutionary approach to be implemented in the field of education. Traditionally, TRIZ was considered a teaching tool for solving nonstandard problems and tasks (using TRIZ tools). At supersystem level, the TRIZ didactics system deals with teaching creative imagination, specifically in the area of TRIZ known as Development of Creative Imagination (DCI). Finally, at the highest level TRIZ didactics can be applied for realization of the TRIZ evolutionary approach in the field of education. But it is necessary to learn TRIZ tools and DCI at first to use this concept. The concept realization is based on TRIZ evolutional maps. Their examples are presented in the report.

The concept of the TRIZ evolutionary approach in education was formed on the basis of 30 years’ experience of teaching TRIZ-DCI at Komsomolsk-na-Amure State Technical University (KnASTU).

Keywords: TRIZ evolutionary approach, education, knowledge systematisation, didactics;

1. Introduction

TRIZ is usually considered a tool best suited to technical problem solving. In many universities worldwide, training using the TRIZ method is based on the didactic aspect of TRIZ that is geared towards problem solving [1]. However, the didactic possibilities of TRIZ are even more extensive.

Henry Altshuller began developing TRIZ on the basis of a problem-solving tool, i.e., the inventive principles of conflict resolution [2], but subsequently came to a decision that the basic tools were insufficient for the successful and effective solving of problems [3]. Instead, he turned his attention to more thought-provoking problem-solving methods [4]. By the time TRIZ was developed in 1946-1948, many new methods had appeared: Osborn’s
Brainstorming [3]; Zwicky’s morphological analysis [4]; Whiting’s focal objects method [5]; Gordon’s synectics [6], etc. Altshuller reformulated aspects of all of those methods. He modified the personal analogies of synectics identification into modelling with ‘smart little people’ [7] and got rid of the negative consequences associated with synectics. In addition, Altshuller elaborated on the inventive principles of imagination development such as decrease-increase and natural law modification, among others. Hence, university professors of TRIZ were able to avail of another good didactic tool, i.e., imagination development, as part of TRIZ. It should be noted that some universities do not place enough emphasis on this didactic tool.

A further didactic aspect of TRIZ is knowledge systematisation. Concepts such as system, systemness and system approach are basic ones in TRIZ, and the rules of system development are also emphasised. It is postulated that any system can be developed from contradiction to contradiction resolution using TRIZ tools (through the inventive principles of conflict resolution, the laws of system evolution, etc.). Human knowledge can be considered a specific system, and if we transfer the rules of system development to that knowledge, it is fair to say that they develop according to TRIZ laws. Thus, students may be trained on the basics of TRIZ systematisation [8] and on the evolution of TRIZ.

Thus the aim of the report is to present the concept of the TRIZ evolutionary approach in education. By virtue of the fact that implementation of the concept is impossible without mastering the DCI discipline and tools of problem solving, three aspects of teaching TRIZ are considered in the report:

- didactics of imagination and mental development;
- didactics of problem solving;
- didactics of knowledge systematisation.

Next, we will deal with the features of all the didactic aspects of TRIZ, and with their interaction and potential improvement.

2. Didactics of imagination and mental development

The Development of Creative Imagination (DCI) is a multistep process. Figure 1 depicts the stages of DCI and DCI interaction with the subsequent stages of TRIZ. During the first stage, students learn one or two pre-TRIZ thought-provoking methods. At Komsomolsk-na-Amure State Technical University, where TRIZ training commenced in 1984, we use brainstorming [3] and the focal objects method [5] (or morphological analysis [4]).

Some peculiarities need to be taken into account when choosing primary methods. Iouri Belski researched the perceptivity of different thought-provoking methods based on students using different thinking styles. Here, Harrison and Bramson categorise thinking styles as follows [9]: synthesists, idealists, pragmatists, analysts and realists. During the first stage, students also learn about forms of thinking, e.g., logical, dialectical, creative, etc. Every form of thinking amplifies thought-provoking methods and prepares students for learning the elements of TRIZ. Dialectical thinking, together with such games as ‘good-good’, ‘bad-bad’ and ‘good-bad’ prepares them to learn and understand technical and physical contradiction concepts. Logical thinking is always required to solve problems, starting with clarifying the wording and definitions (according to the law of identity) and moving on to the process of carrying out subsequent actions while rigidly adhering to logic (according to the law of reasonable grounds). This knowledge is required to learn the Algorithm for Inventive Problem Solving (ARIZ) successfully.

Creative thinking has also been shown to develop the right hemisphere of the brain efficiently.

After learning the pre-TRIZ methods and becoming familiar with some thinking forms, students then study the thought-provoking methods created by Altshuller: the system operator, the ideal final result (IFR), modelling with ‘smart little people’, among others [7]. Students have already been prepared for system thinking by these inventive principles. For example, the twenty-seven screen scheme of system operators trains students on the unity of opposites (aside from the 9 screens of the system itself, it is proposed to have 9 anti-system screens and 9 screens featuring a combination of system and anti-system).
Pre-TRIZ methods do not focus on an ideal result, whereas Altshuller’s inventive principles are free of this disadvantage.

Each pre-TRIZ method only enlarges the field of problem solving and does not propose a procedure for narrowing it.

By the end of the first stage of learning DCI, students should have mastered free idea generation, IFR formulation and the presentation of a system in multiscreen form. A student-centred approach is vital in order for the first stage to be completed efficiently.

The DCI stages that follow are embedded in the main TRIZ tools.

The above-mentioned didactics has been used in teaching DCI KnASTU since 1995. During this time thousands of students of almost all KnASTU Departments both engineering and humanities have been trained. Teaching hours range from 34 to 51 depending on the fields of study and specialties. The subject is trained during one term. There have been investigations of DCI training efficiency in KnASTU [10]. IQ level was estimated before and after lessons. Totally, 145 people from 11 groups of the first, second and fourth year students took part in the research. The average IQ level increased 10 points that corresponds to the number of correct tests done to be up by 24 percent.

So from the above, we can conclude that the first stage of DCI develops thinking and prepares students to learn and understand the basic concepts of TRIZ.

3. Didactics of problem solving

The didactics of problem solving is one of the most investigated subjects of the current day. It is reviewed in the works of I. Belski [11, 12], D. Cavallucci [13, 16], G. Cascini [14], T. Nakagawa [15] and others. We will concentrate on some aspects of problem solving below.

All problems can be divided into three groups depending on the related time tag: operational, tactical or strategic. Each problem type should use its own set of didactics.

Engineering issues are an example of an operational problem. To solve such a problem, the inventive principles of contradiction resolution and suffix field transformation can be used in some cases, but other problem-solving methods are also needed. This is where the elements of DCI come in. In order to solve problems fully, students must learn a technique combining resource determination and the indices of effects (physical, geometrical, chemical, etc.).

Tactical problems require skills that enable us to see possibilities, and for this to happen, it is necessary to know the laws of system development. As per the KnASTU experience, students must first learn the law of completeness, the law of increasing degree of system ideality and the law of evolution along the S-curve. The next step, according
to Litvin and Lyubomirskiy’s approach [17], should be to train in the next set of laws that correlate with the stages of system development in line with the S-Curve.

Solving strategical problems opens new doors to science and technology. To implement these solutions, both classical and modern TRIZ tools are required. However, it is too soon to teach students all of the tools at this stage.

An extended didactic scheme of problem solution is presented in Figure 2.

Training TRIZ tools and the laws of systems evolution started in KnASTU in 1984, but in accordance with the above-mentioned didactics it has been being realized in KnASTU since 1995. This year the Department of TRIZ was founded. During this time more than thousand students have been trained, most of them from engineering departments of KnASTU: mechanical engineering, electrical engineering, shipbuilding, aircraft constructing, and computer technology department in recent years (since 2002). Usually, TRIZ course consists of two subjects. The first subject is the laws of technical systems evolution. Teaching hours varies from 34 to 51 here. The second subject is the technology of creativity, which describes the basic tools of TRIZ. Teaching hours of this subject also varies from 34 to 51.

We can conclude from the above that students are required to learn classical TRIZ tools and the laws of system development.

4. Didactics of knowledge systematisation

Students’ knowledge systematisation is based on the TRIZ concept of knowledge evolutionarity that has been considered in some authors’ works [8, 18, 19]. The main points of this concept will be reviewed below.

4.1. TRIZ evolutionarity

It is postulated in TRIZ that system development complies with objective laws, and those laws are valid for all systems. Altshuller investigated and stated the totality of these laws, and Altshuller’s students have added this totality [20]. According to TRIZ, systems develop from contradiction to contradiction, all the while being resolved by TRIZ tools, and culminating in increased ideality. Human knowledge can also be considered a system or a totality of systems. We shall give an example of development of a system and knowledge about the system. A wheel will be considered. It is a wheel that was discovered by early men. Probably it was a log. The early man laid a log under a load to move it (forces decreased). The first knowledge about a wheel, a primitive rolling movement theory appeared in parallel. As per this theory if a log is rounder then it is easier to move the load. But the early man noticed that if the diameter of a log is larger (and the log is heavier at that time) then it is required more forces to
move the load. The ancient man became to choose thinner, rounder logs but another problem appeared at that time. A thinner log stalls oftener on tussocky, uneven ground. The rolling movement theory did not answer why it had happened.

A contradiction appeared in the technical system: if the weight of a wheel (a log) decreases then its possibility worsens unacceptably.

A contradiction is also appeared in the knowledge (the theory): if the field of theory application extends then its efficiency decreases unacceptably. The contradiction of the technical system was resolved with the “split” inventive principle: shorter logs were used and were laid at the right and at the left sides of the load. The theory contradiction was also resolved with the inventive principle “pass to another dimension”: there was a transition from 2D model of rolling movement to 3D model. The wheel continued developing. An axis, a rim, arms, tires appeared. The theory of rolling movement was accompanied with the theories of elasticity, strength, dynamic influence and others. Thus, the wheel and the knowledge about the wheel have been developing in parallel: both were confronted with contradictions, both developed after resolution of the contradictions with one of the inventive principles.

Here the contradictions resolved with the inventive principles but it can be done using any TRIZ tools: inventive principles of contradictions resolution, sufield transformations, mechanism of system development laws, etc.

Thus TRIZ evolutionarity is a system evolution as a sequence of contradictions and tools of their resolution.

The system evolution is represented with the TRIZ evolulotional map in diagram form.

4.2. TRIZ Evolulional Maps

The TRIZ evolulional maps for technical systems are similar to “trees of evolution” by Shpakovsky [21]. The difference is following: “trees of evolution” are built using only trends of corresponding laws while the TRIZ evolulional maps are compiled with all TRIZ tools. At first the TRIZ evolulional maps for knowledge of applied science will be considered. Diagram forms of these maps may be different. For example, it is a linear sequence (see Fig.3 a) [8], or a totality of linear sequences combined with a base linear sequence (see Fig.3 b) [18], or a unique hierarchy.

The hierarchically embedded maps have the most general view. For example, it is a map of programming paradigm (parents’ map) (see Fig.4 a) [22] and a map of object-oriented programming, an associated map of the relevant paradigm (see Fig.4 b) [23].

It can be seen a “body” and “dry” branches where evolution completed. A unique root element is the general staring point of all maps. There is a combination of branches in some maps (see Fig.4 b) according to the law of mono-bi-poly-mono.
Fig. 3. (a) TRIZ evolution of DRAM addressing system, (b) TRIZ evolution of CASE systems
Maps of applied sciences provide a basis for students’ knowledge systematization. The “body” of a map is the most important for training. Teaching the elements of the central part of the map total volume of information being transferred to students decreases but quality of training is not worse. Future elements of the applied science may be predicted while following the central part of the map i.e. after conceiving the contradiction and resolving it for the last element of the map.

All human knowledge may be presented as hierarchically embedded the TRIZ evolutional maps and it allows following up relations between separate sciences.

4.3. Knowledge systematization using the TRIZ evolutional maps

At the present time students get unsystematized or poor systematized knowledge and skills. Every student create his own knowledge system instinctively (put the knowledge in order) but it is inefficient. This system is different for different sciences and it varies from teacher’s system. As a result a significant part of students’ knowledge is lost. It is proposed to use the TRIZ evolutional maps as a “core” of knowledge system. All teachers of applied sciences should learn and use the TRIZ evolutional maps.

This approach has the following advantages:
- Knowledge system of a student and knowledge system of a teacher coincide.
- Knowledge systems are similar for all subjects.
- Knowledge system has cast-iron logic; each of the following elements of applied science is appeared as a result of contradiction resolution of the previous element.
- It is easy to remember the mechanism of transition from element to element as there are few TRIZ tools.
- Students practice TRIZ tools and show positive results in untypical problems solving.
- Students develop their brainwork intensively as moving from element to element they have to pass from conceiving an inventive principle of contradiction resolution to the concrete result that is a new element of knowledge.
The didactics of training systematized knowledge is following. Students learn DCI completely. Then student study all TRIZ tools. If they cannot do it then only inventive principles of contradiction resolution should be examined. Later students learn a subject using the TRIZ evolutional map. Training numerical methods will be considered for example. Students learn elements of the basic horizontal line of the TRIZ evolutional map [17] (Fig.5). This is evolution of simulation model of investigated technical subject in numerical techniques. Learning starts from the easiest model, i.e. the linear equation system. It is explained by an example how to describe the subject with the linear equation system and what is the object of doing that. Then the task is complicated; students should describe the subject in detail. Students see that problems of large volume of calculations appear. Students must find a contradiction and resolve it with TRIZ tools i.e. to propose the next more ideal simulation model of subject description. If it is required a teacher helps students. The first steps finishes here.

Thereafter the students “open” all following models and start learning vertical lines of development. All steps are repeated except for a method and its mathematical implementations are examined in detail. The above-mentioned way is used for the whole map starting from the easiest technique up to the most difficult one.
The same didactics may be used for others TRIZ evolutional maps, see Fig. 6.

Some elements of the described approach have been being practiced in KnASTU from 2010. The "Decision-making theory" was chosen as a basic subject for the experiment. Future specialists and masters of the department of computer technology studied the subject. The students studied the classical Analytic Hierarchy Process, then identified disadvantages (usually 4 or 5), formulated contradictions (usually 2 or 3) and using the inventive principles of contradictions resolution suggested one or two resolutions. At last the teacher chooses on resolution that corresponds to the concept of TRIZ evolution.

Totally, 42 students participated in the experiment. The efficiency of the method was evaluated qualitatively by the opinion of students.

Conclusion. To systematize the knowledge using the TRIZ evolutional maps, students should master the DCI, TRIZ tools and "rediscover" step-by-step the elements of the corresponded subject areas.

5. Discussion

As per our investigations TRIZ can be used in one more very important subject area that is to be a basis for students’ knowledge systematization.

The author is quite aware that implementation of this system in teaching special or elective courses is concerned with difficulties and obstacles.

While increasing contradiction between the scope of knowledge and time for its learning it is required to look for new educational approaches.

Imparting systematized knowledge in brief will allow not only to resolve this contradiction but also to be a tool for production new knowledge of students.

6. Summary

The new approach to training the applied sciences at university was considered in the report. This approach is based on the model of TRIZ evolution of knowledge. The evolution of knowledge is reviewed as a transition from contradiction to contradiction by their resolution with TRIZ tools.

The technique of the present approach consists of 2 stages. At the first stage TRIZ evolutionary structures of a subject is formed. At the first step of this stage the basic didactic element is defined. This element will be a start point for teaching the subject. Disadvantages of this element are specified especially after its extension. Physical and technical contradictions that reflect the disadvantages are determined. TRIZ tools that resolve the contradictions, another didactic element realizing this tool are also defined at the first step. As a result the first iteration of the TRIZ
evolutional map is built (see item 4.2). At the end of the first step the students solve the assignment and meet with contradictions in practice. At the next steps of the preliminary stage the full TRIZ evolutional map of the subject is built in same way and tasks batch that help students to find the contradictions is formed.

The students are trained according to the TRIZ evolutionary approach at the second stage (see item 4.3). At the first step the students learn the basic didactic element. Then the students solve an assignment and meet with the contradictions of this element. Using knowledge and skills that they have received after learning TRIZ and DCI the students find and formulate contradictions; choose a TRIZ tool that help them to resolve the contradictions; and suggest variants of the basic didactic element that realize these tools. The teacher follows students’ work and helps them if required. At the end of the first step the teacher choose the “correct” variant of the basic didactic element and the students study this variant. At the following steps the students learn all didactic elements in TRIZ evolutional map in the same way.

As it is very important to learn TRIZ and DCI to realize TRIZ evolutionary approach it is proposed the examples of didactics of these subjects in the report. The present didactics have been being improved at KNASTU during 30 years.

References

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