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A Theory for solving inventive tasks: is it another rationale for technology education?

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Abstract

Different rationales for technology education depend highly on the social context in which the subject was developed. In Russia it is claimed that the development of students' creativity is one among four aims of technology education. This paper analyses the meaning of the concept as it is presented in educational documents, within the context of Russian educational reforms that emphasise mastery of content as an important aim of education.

This paper examines TRIZ (a theory for solving inventive tasks, with the acronym TRIZ derived from the Russian title for the theory) that has been developed as a framework for invention in engineering and compares it to the design-based approach to technology education. The paper argues, on the basis of existing research that the philosophy of TRIZ and its methods can be used as a rationale for technology education in particular contexts. However, it is argued further that TRIZ tools such as inventive principles as well as 'psychological operators' aiming to reduce psychological inertia can be used effectively in the development of student's creativity in any context.

Key words: students' creativity; TRIZ (theory for solving inventive tasks); rationale for technology education; social context

Introduction

A design-based approach (DBA) to technology education, and TRIZ (the theory for solving inventive tasks, known by the English translation of the original Russian acronym) (Altshuller, 1973), were competitors for reforming Labour Training in Russia. At the beginning of the 1990s when the DBA was brought from the West and was considered as an important approach that helps to develop problem-solving capabilities in students, many educators questioned this, asking why TRIZ has not been used as a rationale for technology education? TRIZ was specifically designed initially, to teach engineers, and then students, to find innovative solutions for technological problems. Currently, design-based approaches appear to have won the battle due to the enthusiasm of the people involved. However, the question remains: can TRIZ be used as the rationale for technology education? Would it present a better rationale for particular contexts?

There are historical parallels to the DBA versus TRIZ question. One such story relates to the construction of the Britannia Bridge. The construction of the tubular bridge by the English engineers was a very challenging task in the 1830s. The knowledge from preliminary experiments was clearly insufficient. Hodgkinson's empirical work provided the basic source of knowledge on the buckling of thin-walled structures (Rosenberg & Vincenti, 1978). The theory for shearing loads in beams had just been worked out by Jourawski in Russia and was not yet known in Western Europe. "Thus no theoretical basis was available for analyzing the catastrophic buckling of the sides that appeared in the second test of the model"(Rosenberg & Vincenti, 1978, p.28). The bridge was designed by means of experimental investigations and the design was heavier than it needed to be. Jourawski later made an extensive critique of the bridge design based on his theoretical understanding of shearing loads (Rosenberg & Vincenti, 1978).

This story provides an example of two different approaches to problem-solving. Trial and error approach can bring results, but not necessarily the optimum ones. Theory, however, can provide knowledge that will optimise the solution. Thus, both DBA and TRIZ associated with these two approaches can be used as rationales for technology education aimed at the development of students' creativity in problem-solving. Is one better than the other?

Creativity as mastery of the content

Technical creativity has always been a feature of the Russian educational system. In Labour Training it was mainly achieved through the extra-curricula activities in which students were involved after classes at school and at the Palaces of Young Pioneers where they engaged in searching for technical solutions for problems. Currently, the development of creativity is one of the four aims of technology education which include:

- to develop students *politechnically*, to acquaint them with modern and prospective technologies of processing materials, energy and information via the application of knowledge in the areas of economics, ecology and enterprise; develop general working skills;
- to stimulate the creative and aesthetic development of students;
- to acquire life-needed skills and practices, including the culture of appropriate behaviour and non-conflict communication in the process of work;
- to provide students with the possibilities of self-learning and studying the world of professions, the acquisition of work experience which could be the basis for career orientation. (Lednev, Nikandrov, Lazutova, 1998, p.248)

These aims are part of the overall *Strategy of modernisation* (2001) of Russian education. The main emphasis in the modernisation of school content is on the development of the 'cultural' person who would potentially be able to solve problems in different fields. Thus, a potential ability to solve problems is considered as a major goal of education that can be achieved by mastering the content of education, structured on the basis of different spheres of human activities that constitute the culture. These comprise: cognitive, civic-social, socio-working, household and culture-leisure spheres:

- Competencies in the sphere of cognitive activities (based on methods of mastering strategies for acquiring knowledge from different sources of information)
- Competencies in the sphere of civil-social activities (roles of the citizen, voter, consumer)
- Competencies in the sphere of socio-working activities (including the ability to analyse the situation in the labour market, evaluate personal professional abilities, orientation to the norms and ethics of labour relationship, etc.)
- Competencies in the household sphere (including aspects of health, family well-being, etc.)
- Competencies in the area of culture-leisure activities (including choice of the ways of using non-work time that culturally and spiritually enriches the person).

This represents a significant change from previous beliefs. Twenty years ago the aim of the school was to provide systematic knowledge and skills. Now education is the process of pedagogically organised socialisation aimed at the interests of person and society' (BSE: 1999, p. 62 in Lebedev, 2001. The person should be socialised into the Russian *culture*. Before, there were two equally important aims of education: to educate and to upbring/socialise were separated. Now the current educational modernisation policy argues for socialisation via education. Socialisation, according to Lebedev (2001) is understood as 'mastering the culture of society, which provides the possibility for a person to be the subject of activity, to carry out different social roles' (p. 11). Mastering culture is viewed as a basis for developing the capability of a person to act.

Lebedev (2001) claims that 'the main result of school education should be the readiness and ability of young people, school graduates, to take responsibility for personal well-being as well as for the well-being of society' (p. 6). This potential character of results correlates with the cognitive approach to competency construction (Norris,1991) where competence is about potential but performance is about actual situated behaviour. For example, competence is the knowledge and rules that are necessary for a linguistic performance (Chomsky as stated by Norris, 1991). Thus, the mastery that Russian students should achieve in different areas of activities can be described as having a potential nature, it should give them the ability to solve problems creatively when they need to.

Russian key competencies are different compared to western competencies where they are employment-related. While viewing the competency approach to education as a world practice they perceive it as suitable to the Russian educational tradition, viewed as an orientation on the scientific vision of the world, on spirituality, and activity as a member of society (Russian Ministry of Education, National Fund of Development of Human Resources, 2001, pp. 4- 5).

The development of students' creativity is based on mastering the culture- structured content, and thus, TRIZ appears to be a more appropriate strategy for achieving this purpose in this particular context, as it provides an approach to master problem-solving process in technology education.

TRIZ

The theory for solving inventive tasks, was developed in Russia in the nineteen-sixties and used initially as a framework for creating original and easy to implement solutions in engineering. More recently, it has been applied as a general framework for improving inventive thinking within secondary schools in Russia. Altshuller began developing TRIZ as a pure engineering science, based on the statistical research of patents and other sources of technical information. The goal of this research was to reveal the 'patterns of innovation' so that they could be exploited for the purpose of advancing technological systems. Altshuller (1973) established the following procedures to develop this methodology for creative problem solving:

- Accumulate a data bank of numerous creative solutions (inventions, for the technological arena);
- Identify different levels of creative solutions, then select the high-level solutions from the data bank;
- Reveal typical patterns by which creative solutions of different levels are obtained (innovation principles, patterns of evolution, etc.);
- Develop algorithms for obtaining these solutions.

This analysis has been used to argue that there are a number of objective rules in the development of any technological system. This part of the argument is in accord with the views of some philosophers of technology such as Elull (1987/1990) who postulate that technical development is "as much the result of human choice as it is of technical determination. The technical universe also makes determinations that are not dependent on us and that dictate a certain use" (p. 37). Technique has "its own weight, its own determinations, its own laws. As a system it evolves by imposing its own logic" (p. 150). The essence of TRIZ is seen as recognition that technical systems evolve towards increasing functionality ('ideality') by overcoming contradictions, mostly with minimum introduction of new resources. Thus, for inventive problem-solving, TRIZ provides "a dialectic way of thinking, i.e., to understand the problem as a system, to image the ideal solution first, and to solve contradictions" (Nakagawa, 2001, p.1). Thus, TRIZ has a different starting point compared to invention heuristics developed within psychology.

At it's very highest level, TRIZ may be seen as the systematic study of excellence. There is no one definitive version of a TRIZ process.

For example, Mann (2002) presents TRIZ as a hierarchy.

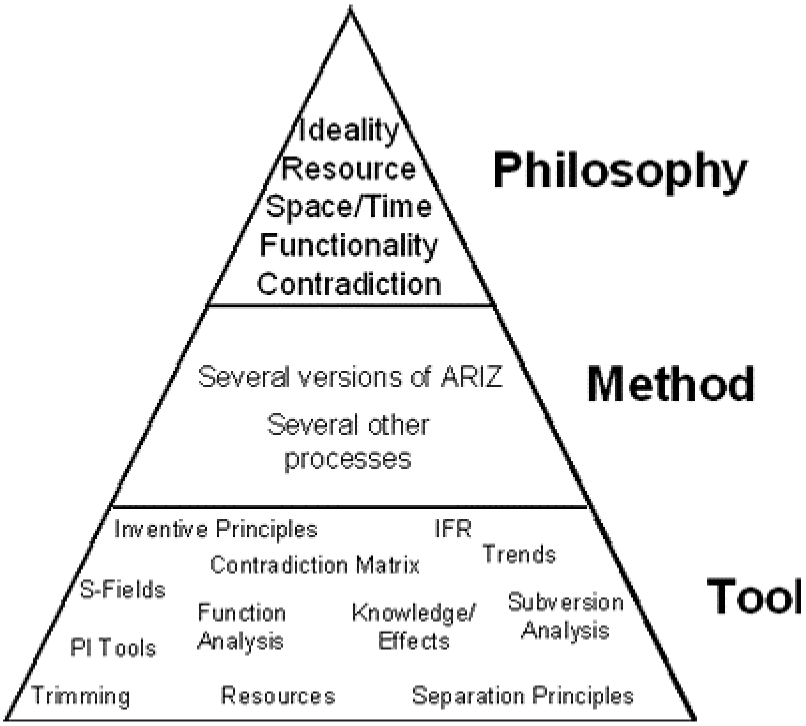

Figure 1: Hierarchical View of TRIZ

The five key philosophical elements of TRIZ are: *Ideality* - and the concept of systems evolving to increasing good, decreasing bad; *Resources* - and the concept of minimizing resources; *Space/Time* - and the importance of viewing systems in terms of their space and time context; *Functionality* - and the over-riding importance of function when thinking about systems; and *Contradictions* - and the concept of contradiction elimination as a primary evolution driver (Altshuller, 1973). Some of these are unique to TRIZ; some have parallels within other similar studies of creativity.

At the bottom of the TRIZ hierarchy, there are a wide-ranging and comprehensive series of tools and techniques for solving different technological problem that may be encountered. For example, 40 inventive principles provide guidelines for finding a solution for particular problems. Three principles illustrate the point.

Principle 1. Segmentation
- Divide an object into independent parts (*Replace mainframe computer by personal computers; Replace a large truck by a truck and trailer; Use a work breakdown structure for a large project)*
- Make an object easy to disassemble (*Modular furniture; Quick disconnect joints in plumbing*)
- Increase the degree of fragmentation or segmentation (*Replace solid shades with Venetian blinds; Use powdered welding metal instead of foil or rod to get better penetration of the joint).*

Principle 2. Taking out
- Separate an interfering part or property from an object, or single out the only necessary part (or property) of an object (*Locate a noisy compressor outside the building where compressed air is used; Use fiber optics or a light pipe to separate the hot light source from the location where light is needed; Use the sound of a barking dog, without the dog, as a burglar alarm).*

Principle 32. Color changes
- Change the color of an object or its external environment (*Use safe lights in a photographic darkroom).*
- Change the transparency of an object or its external environment (*Use photolithography to change transparent material to a solid mask for semiconductor processing. Similarly, change mask material from transparent to opaque for silk screen processing).*

At the middle level there are a number of methods that string the tools together in a way that is appropriate for a particular user. The algorithm of solving inventive tasks (in Russian the abbreviation is ARIZ) is the central analytical tool of TRIZ. Its basis is a sequence of logical procedures for analysis of a vaguely or ill-defined initial problem/situation and transforming it into what is described as a distinct System Conflict. Consideration of the System conflict leads to the formulation of what is described as a Physical Contradiction which is eliminated by providing maximal utilization of the resources of the subject system. ARIZ puts together in a system most of the fundamental concepts and methods of TRIZ such as Ideal Technological System (Ideal System), System Conflict, Physical Contradictions, Substance-Field Analysis, Standards and the Laws of Technological System Evolution.

Altshuller also developed the strategy he called the Lifetime Strategy for a creative individual. This consisted of what Altshuller regarded as effective actions for an individual to develop and implement high-level creative goals. The following qualities are those defined as necessary to become a lifetime creator:
- A significant personal goal
- The ability to create and carry out an action plan
- Being a hard working individual
- Being experienced in the use of creative problem-solving techniques
- Being persistent
- The ability to achieve intermediate useful results (i.e, to ascertain that you are ‘ on the right track’

This multi-dimensional, multi-level theory for solving inventive tasks provides a potentially rich ground that can be used to develop students’ creativity during technology education classes.

TRIZ or DBA as rationale for technology education?
What can be seen as the major differences between TRIZ and DBA?

The major differences between traditional TRIZ and design-based approach to technology education are as follows:
- TRIZ is aiming to *overcome* identified *conflict* whereas DBA aims to find an optimum *balance* between confronting elements. The TRIZ theory identifies a number of different types of technological solutions. The first type is described as a design solution, where the key feature of the process is the search for a compromise. The second type is defined as an inventive solution, where the key feature involves overcoming contradictions. The concept of increasing ideality is regarded as the over-riding trend of technology evolution. The ultimate limit of ‘ideality’ is the Ideal Final Result (IFR). The IFR is a simple and yet profound concept which says that systems will evolve to deliver all desired benefits, without any costs or harm.

- TRIZ is oriented to the problem, not to the client. TRIZ puts a special emphasis on the technical side of a solution – function and materials, comparing to DBA that put a special emphasis on aesthetics that is regarded as an extremely important feature in contemporary Western society (Pavlova, 2002).
- TRIZ is a very complex tool that cannot be learnt very quickly whereas DBA required less time to understand. Practitioners who are teaching TRIZ argue that mastering ARIZ is the most time-consuming and difficult task (Mann, 2002; Domb, 1997). Thus several simplified form of ARIZ have been proposed (Nakagawa, 2000) to help students get started, and gain some of the benefits of TRIZ. This boosts their confidence, as well as their knowledge, so that they will be willing to spend the time that mastery requires (Domb, 1997).
- It is generally necessary to master TRIZ to a very high level of competence to achieve successful result. DBA can be used successfully at different levels.
- TRIZ and DBA have been developed on the basis of two very different traditions - engineering for TRIZ and humanistic (or consumerism as the worst version) for DBA.
- Learning patterns are different. In TRIZ students learn theory first with a lot of examples to illustrate the particular principle or particular approach. In DBA students can learn using both ways, the path from practice to theory is considered as extremely useful.
- TRIZ is more effective in producing innovative 'guaranteed' results in a systematic manner. World-wide distribution and further development of ideas are reflected in the establishment of several centres in the USA, including the Altshuller Institute, conferences on TRIZ in Europe and the USA and active research undertaken by several institutions in Japan and Israel. Research (Helfman, 1992; Clausing, 2001; Manor, 2002) has provided findings that suggest that TRIZ improves students' inventive thinking abilities.

In the context of an orientation to developing students' creativity through the process of mastering TRIZ, TRIZ can be regarded as a possible rationale for technology education within a particular context. Elements of TRIZ such as tools (40 inventive principles, etc) or 'psychological operators' that facilitate the creative process such as course in Creative Imagination Enhancement (CIE) that is aimed at reducing psychological inertia (including Smart Little Creatures Modeling and Dimension-Time- Cost operators) can be used in the classroom to enhance students creativity. In this case they can be compared with heuristics and psychological methods of development of students' creativity.

Conclusion

To conclude, this paper has described the features of a theory for solving inventive tasks that is little known in western countries in the context of technology education. The theory is known as TRIZ, and it is compared with design-based approaches currently being employed as rationale for technology education in western countries. There appears to be sufficient evidence of the viability of TRIZ in developing the creative thinking abilities of students. TRIZ appears to provide strategies additional/alternative to those used in DBA approaches and has received sufficient attention and research since becoming available in the West to warrant consideration as both an additional rationale for technology education in a particular context and as a set of tools (principles and strategies) for developing or improving students creative thinking abilities in any context.

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