Teaching Disadvantage as an Appearance of Contradiction in Basic TRIZ Education

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Abstract

In order to simplify realizing main categories of TRIZ and shorten the learning curve for basic TRIZ education, a new instrument is suggested. This instrument is based on the concept of disadvantage (DA) as a shortened and easier understandable form of physical contradiction. We suggest a new classification of DA that are generalized in five groups depending on the kind of critical resource of a system: Substance, Field, Time, Space, and Function, with total 30 typical DA. By analyzing the data about 5000 known inventions that came to the market, we have found most typical inventive principles, standards and trends known in TRIZ that are frequently used for overcoming each type of DA. The new tool links typical disadvantages to corresponding principles, standards and trends. Our practical experience of TRIZ education (in the form of coaching) demonstrates that the students better realize the studied TRIZ tools (trends, principles, standards), faster find the solution, and resolve greater percent of problems; therefore, the education becomes shorter and more effective.

Keywords: TRIZ, disadvantage, contradiction, principles, trends, standard solutions

1. Background

One of the main problems in TRIZ education is too long learning curve caused by considerable conceptual difference between TRIZ and classical engineering disciplines. In particular, this difference appears in the TRIZ concept of contradictions in technical systems.

All main instruments of classical TRIZ (inventive principles, standard solutions, ideal final result, trends of engineering systems evolution, ARIZ) are based on general concept of contradiction in a Technical System (TS). TRIZ operates with several kinds of contradictions; among them, the most usable are Technical Contradiction (TC) that describes undesirable consequences of improving TS (if we do something with the system then we improve A but inevitably worsen B), and Physical Contradiction (PC) that describes opposite requirements to the same parameter of TS (the value of parameter P should simultaneously be big to achieve desirable result C and small to achieve desirable result D).

At the same time, our experience and experience of our colleagues demonstrates that the students, especially outside of the former USSR, and specifically in the Eastern Asia (Korea, China), hardly accept this concept that is in strong contrast with educational and even mental paradigms that dominate in these countries.

Indeed, in the Eastern and, with some stipulations, Western universities the future engineers study the Technical Systems (TS) as holistic objects that work in the prescribed manner, in order to satisfy some or other human need for which they have been developed, e.g. transportation, communication, protection from something, etc. This model does not consider the existence of any “contradictions” in the system. As a result, the TRIZ teachers (trainers, coaches, facilitators) may spend a lot of time trying to teach students the concept of contradiction, but be not much successive.

On the other hand, our experience demonstrates that if we present the same concept in a little bit different form, by changing the term “contradiction” for “disadvantage” (DA), most of students easily realize the key points of this concept. Indeed, for any engineer it is self-obvious that any technical system, from the simplest hand instruments to such large and complicated ones as a spacecraft or superliner, has some or other disadvantages, and their overcoming is usually the main task of a real-world engineering project. Thus, thinking in terms of disadvantages looks natural and does not cause mental abruption.

In this paper, we use the term “disadvantage” as a synonym for “undesirable effect”. With the term "disadvantage", we underline the practical focus of TRIZ instruments: to get a competitive advantage, to make a new or improved system better than its previous variant; in other words, to suggest something that satisfies objective requirements to a system, not somebody's desires.

The above-mentioned word replacement changes nearly nothing in essence, as far as, according to the main positions of classical TRIZ, any disadvantage in the system is a consequence of some or other contradiction, and it can be reduced to this contradiction. The problem, in our opinion, is psychological: in a typical TRIZ educational program, the term "contradiction" appears too early, without proper background. Below, we suggest the concept of disadvantage as a key point of such preliminary education.

We have to note that nearly all programs of TRIZ education were originated from the USSR/Russia and became adopted (in most cases, implicitly, without any special stipulations) to the Russian mentality and specific educational system. In particular, for most of Russian (and former Soviet) engineers, contrary to their Western and especially Eastern colleagues, disadvantage in a system is so much "natural" phenomenon that it does not require special education. Another significant difference between countries concerns basic education: up to very recent years, Russian students of any specialty learned a special course of dialectics where the term "contradiction in a system" was one of the key points. Thus, for Russian students, learning "contradictions" looks quite natural and does not need any preliminary steps, whereas outside of Russia the situation is something different.

Thus, we suggest the concept of disadvantage-oriented education as a first, preliminary step to deep understanding the main TRIZ categories. At the same time, we found this approach quite sufficient for explanation and basic practical use of such TRIZ tools as inventive principles, basic trends of engineering systems evolution (TESE), and some of standard solutions. And after that – not before! – explanation of the term "contradiction" as a mechanism of "functioning" these, basically already known, instruments does not cause mental abruption by students.

Below, we suggest a new educational instrument that we widely use in our classes of basic TRIZ education: a handbook of typical disadvantages.

2. Prior art

The problem of shortening the "learning curve" is not new in TRIZ. The founder of TRIZ Genrich Altshuller made much effort to make basic TRIZ education faster and more efficient. One of the first attempts in this direction caused the development of the worldwide-known Contradiction Matrix (Altshuller, 1973 & 1999). The author analyzed many descriptions of the inventions and suggested the most popular inventive principles that were used to resolve technical contradictions with the same type of conflicting parameters. This instrument was then criticized many times (mostly, on the sidelines) for low practical efficiency, but up to now it remains one of the most popular TRIZ instruments available for beginners. A new version of this instrument was suggested in (Mann, 2004) where the list of conflicting parameters was extended for total 50 items.

Other classical tool that was developed with the same goal (to shorten the "learning curve") was a set of standard solutions (Altshuller, 1975 & Bukhman, 2014). The idea of this instrument was to simplify the use of rather complicated instrument, ARIZ, for the most typical problems that often have similar solutions. This tool also includes a classification based on Substance-Field modeling.

Standard Solutions and Inventive Principles are internally connected with each other. In (Domb et al., 1999), their relationship is described and tabulated: for each of inventive principles, the authors specified one or more standard solutions that use this principle. Essentially, the mapping table suggested in (Domb et al., 1999) can be considered as a new classification of standard solutions.

Similar solution was suggested by Fedosov (2009) to simplify teaching the concept of function: the author compiled a "handbook of elementary functions" that covered the majority of practical situation requiring functional analysis. Then, a rather complicated and error-prone procedure of formulation of particular functions was replaced for selection of proper function from the list. Similar idea was suggested in (Kynin & Priven, 2013).

If we try to integrate the basic ideas suggested in these and many other papers, we can formulate the "mainstream" of suggested solutions as follows:

(1) Specify the category which learning is difficult ("function", "contradiction", etc.);

(2) Suggest a new classification of this category basing on its key element ("conflicting parameter" for TC, "substance-field model" for standard solutions, etc.);

(3) Suggest a simple way of attribution of a particular problem to a corresponding class of this classification;

(4) For each class of the suggested classification, specify one or more typical (popular, frequently used) instruments that effectively work with this class of problems.

In this paper, we apply the same general strategy to disadvantages.

3. Relationship between disadvantage and physical contradiction

The concept of disadvantage is not somewhat foreign for TRIZ. The use of all known versions of inventive algorithms (ARIZ-85, ARIZ-CMBA, AVIZ, etc.) start from the description and definition of some "inventive situation" in terms of some or other inconvenience in the prototype, unsatisfactory complexity of performing the function, too high cost, etc. All of these issues characterize disadvantage of the existing system as the first, basic category to be analyzed. Then we convert the description into the "language" of parameters and build a TC for understanding of the causal link of this DA. Afterwards, we built a model of PC as a new heuristic single-parameter model where the DA is considered in the form "a parameter P should be big (for something) and small (for something else)". Then we build the next heuristic model of the DA on the base of concept of Ideal Final Result (IFR), with two key phrases: (1) my new system contains some "X-element" that causes disappearing the DA, and (2) the new system prevents the DA itself, without special intervention. The solution of this "equation system" (finding a common solution for all of these models) helps a solver to focus his/her thinking to search for a solution as some image, "portrait" of possible solution that overcomes the initial DA.

As follows from the above reasoning, the DA is a key category in the process of the development of a new TS, as far as the concept of DA is used in some or other way in all instruments of classical TRIZ: in TC, PC, IFR, standard solutions.

Basing on this general understanding, we suggest a rather simple classification of the most "popular" typical DA that force a solver to find a new inventive solution of a problem.

We have to notify that G. Altshuller tried to do something very similar in the Appendix 1 to ARIZ-85C (Altshuller, 1985 & Marconi, 1998) where he described 11 typical models of conflicts. Unfortunately, our experience shows that practical use of this classification in TRIZ education is rather difficult: the students very often confuse different kinds of conflicts, improperly determine their "sides", and, as a result, just "draw a picture" instead of understanding the nature of the conflict.

Again, we see the probable reason of this difficulty in psychology: the mentally negative word "conflict" is inconvenient and needs replacement. In our opinion, much more convenient and habitual language uses no "conflict" but "parameter". Such approach significantly simplifies education.

For example, it is very easy to describe the disadvantage of a pencil in the form: "long use of a pencil causes pain in fingers of an arm that holds it". After some analysis, we could formulate a TC that connects the time of use with some characteristics of the pencil itself, i.e. its hardness, and then move to a PC where this second parameter (hardness) is used: "hardness of pencil should be big to save the shape of pencil and small to avoid causing the pain in fingers".

Operating with the parameter "hardness" simplifies the search for a proper solution. However, to come to this "secondary" parameter we need considerable time and effort. At the same time, if we come back to the source formulation we can see that it already contains some parameter: time of use. In fact, we can rewrite this formulation in the form of PC: "time of use should be big (to write the required text or draw picture) and small (to prevent the pain in fingers)".

The experienced TRIZ specialists often call such PC-like formulas derived from the source problem formulation as "proto-PC" or "initial PC". The general recommendation is not to try to resolve this "proto-PC", as far as the information about the problem is often insufficient, and continue the analysis to formulate the "proper PC" (in our case, concerning the hardness of pencil). The same recommendation can be derived from the text of ARIZ (Altshuller, 1985) where the initial formulation should be transformed to a TC and only afterwards to a PC. Reasoning about "erroneous" intension to resolve PC without formulating TC can be found, for example, in (Goldovsky, 2014) where the author underlines limited application of such simplified approaches. We completely agree with the last statement and consider only the situation of basic TRIZ education within very limited time (1-2 working days for the course), as far as such time limit was specified by very many our customers.

Analysis of about 5000 inventions realized in the commercially successful products showed some essential relationships between the kinds of parameter mentioned in a "proto-PC" and particular TRIZ instruments (principles, trends, standard solutions) that typically allow resolving the problem. For example, the problem of expendable substances (that we can rewrite in a "parametric language" as "too high consumption of substance") is very often solved by using the trend "transfer to Super-system": pen transforms to computer (eliminating the ink), oven transforms to electric cooker (eliminating the fuel), etc. In other words, problems with similar disadvantages often have similar solutions.

Note that similar idea is indirectly used in the Functional Oriented Search (see e.g. Litvin, 2005): if a problem is properly formulated in the "language of parameters" then (after translation to the "language of functions") it is possible to find a solution in some far enough domain area and use its operation principle to improve the source system. In other words, there is a rather high probability to find similar (working!) solutions for systems with similar disadvantages initially formulated in terms of the same parameters.

Below, we describe a new instrument that integrates significant parts of our knowledge about DA and their connection with the instruments of classical TRIZ. Not using the term "contradiction" directly, this approach indirectly gets the students to understanding of the essence of this term, so that its further explanation appears "painless" and mentally appropriate.

4. Use of classical TRIZ tools in connection with typical disadvantages

As it was stated above, to practically use the idea of "similarity by disadvantage", especially in basic TRIZ education, we need some simple and convenient classification; in our case – the classification of disadvantages.

Earlier (Danilovsky, 2011), we suggested a new classification of disadvantages basing on the use of five general categories that are widely used in TRIZ: time, space, field (energy), substance, and function. This classification contained 36 typical DA. However, our experience in TRIZ consulting and education shows that six of them have never appeared in our projects (we tried to apply this approach backdating to several hundred previous projects). Thus, we consider reasonable to exclude these six types of DA from our classification to reduce the "information noise".

The suggested classification is presented in Table 1. This classification was derived empirically and, therefore, does not pretend to be complete. However, it covers an overwhelming majority (about 80%) of real-world problems that we resolved last time.

Table 1 List of 30 typical disadvantages.

##	Description
Substance	
1	Undesirable substance
2	Disposable substance
3	Low productivity of using substance
4	Low usable energy of substance
5	Need to remove substance
6	Insufficient control of substance flow
Field	
7	Undesirable field
8	High weight
9	High energy consumption when using
10	High energy consumption when preparing to use
11	High energy consumption when switching
12	Many moving parts
Space	
13	Big size when transportation
14	Big size when storing
15	Improper shape
16	Trivial shape (and color)
17	Small distance of useful action
18	No mobility
Time	
19	Short life time
20	Long time of charging
21	Small resource of autonomous work
22	Long preparation to use
23	Long operating time
24	Long learning curve
Function	
25	Needs correction function
26	Excessive level of function
27	Insufficient level of function
28	Insufficient additional functions
29	Insufficient reliability
30	Requires additional system

In the Table 2, we summarize the results of our analysis of about 5000 inventions realized in commercially successful products concerned different industries: household appliances and housewares (about 1700), car and machinery (about 1500), little consumer things and toys (about 800), chemistry and agriculture (about 350) and others (the rest).

Table 2 Most popular TRIZ tools recommended for overcoming the disadvantages specified in Table 1.

DA ##	Trends	Standard solutions (Altshuller, 1975)	Inventive principles (Altshuller, 1973)
1	Ideality MATCEM Harmonization	2.2.5, 3.1.5, 5.1.1.1, 5.1.3	2, 9, 10, 11, 22, 23, 24, 31, 34, 38, 39
2	Supersystem Macro-micro Ideality	3.2.1, 5.1.1.1, 5.1.3	13, 28, 35, 36, 25
3	MATCEM Conductivity Ideality	1.1.1, 1.1.4, 1.1.5, 2.2.2, 2.2.4, 3.2.1, 5.2.1, 5.2.2	9, 14, 18, 34, 38
4	MATCEM Macro-micro Ideality	1.1.2, 1.1.5, 2.3.1, 5.3.1	35, 36, 38, 39
5	Harmonization Supersystem Macro-micro	1.1.6, 3.1.3, 3.2.1, 5.1.3	1, 5, 6, 9, 10, 14, 16, 25
6	Completeness Harmonization Dynamization	1.1.3, 2.3.3, 5.2.3	1, 2, 3, 7, 15,13, 19, 20, 24, 25,31
7	MATCEM Macro-micro Harmonization	1.1.5, 1.1.6, 1.1.7, 1.1.8, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 3.1.3, 4.5.1, 4.5.2, 5.1.1.1, 5.2.1, 5.3.3, 5.3.4	1, 2, 3, 7, 11, 17, 24, 35, 40

DA ##	Trends	Standard solutions (Altshuller, 1975)	Inventive principles (Altshuller, 1973)
8	Dynamization Supersystem Harmonization	1.2.2, 1.2.4, 5.1.1.1, 5.1.4	8, 15, 28, 29, 30
9	Supersystem Macro - micro Ideality	2.2.2, 3.1.1, 3.2.1, 5.2.1, 5.3.2, 5.3.5	35,36,12,28, 1
10	Completeness Conductivity Dynamization	2.4.1, 3.1.5, 5.1.1.1, 5.2.1, 5.4.1	9,23,15,17
11	Ideality Conductivity Supersystem	3.1.5, 5.2.1, 5.4.1	12,15,17,10,25,23
12	Macro – micro MATCEM Conductivity	1.2.2, 1.2.4, 3.1.5, 3.2.1, 4.1.2	9,10, 28,30, 35, 36, 26,13
13	Dynamization Ideality MATCEM	2.2.4, 3.1.2, 3.1.5, 5.1.4	7,15,17,28,29,30,35
14	Dynamization Harmonization Supersystem	2.2.4, 3.1.5, 5.3.1	7,18,17
15	Harmonization Dynamization Ideality	2.2.4, 3.1.2, 5.1.4	2,3,4,7, 15, 19, 23, 23, 28.
16	Ideality Supersystem Harmonization	2.2.4, 3.2.1	32,26
17	Completeness MATCEM Supersystem	3.1.1, 3.1.4, 5.2.2	19,20,22,8,23,28,35
18	Supersystem Dynamization Ideality	5.1.4, 5.4.1	2, 17,15,13
19	Harmonization Ideality Dynamization	1.2.3, 1.2.4, 3.2.1, 5.1.1.1	9, 10, 3, 29, 30,39,40,34
20	Harmonization Ideality Dynamization	2.2.4, 5.3.5, 5.1.1.1	1,10,12,7,18,23,34
21	MATCEM Macro - micro Ideality	3.2.1, 5.3.5, 5.4.1, 5.5.1	28,35,36,19,20,12
22	Supersystem Macro - micro Ideality	1.2.2, 1.2.4, 2.2.4, 2.2.6, 3.1.2, 5.1.1.1	10, 1,2,7,23,25
23	Completeness Dynamization Supersystem	1.1.1, 1.1.5, 1.1.8, 2.2.4	14,18,21,7,15,17, 2,9,10
24	Supersystem Completeness Dynamization	2.2.4, 2.3.1	25,13,20,17,2
25	Ideality Supersystem Dynamization	2.3.1, 2.3.2, 2.1.2, 2.2.3, 3.1.3, 4.3.2, 4.3.5, 4.4.2, 4.5.2	6,25,20,24,23,2,28
26	Harmonization Ideality Completeness	1.1.3, 1.1.5, 1.2.4, 5.1.1.1	19,25,23
27	Conductivity Completeness Dynamization	1.1.1, 1.1.3, 2.1.2, 2.2.2, 2.4.11, 4.2.2, 4.4.1, 5.1.2, 5.4.2	12,20,14,18,21,28,22,23,15,13
28	Ideality Completeness Supersystem	2.2.1, 3.1.1, 3.1.3, 4.2.1, 4.3.1, 4.4.1, 5.3.1	6,20,32,25
29	Completeness Dynamization Ideality	1.2.1, 1.2.2,1.2.3, 2.2.3, 2.4.3, 2.4.8, 3.1.1, 4.4.1, 5.1.1.1, 5.4.1	5,2,12,19,20,23,24,25,33, 38,39,11
30	Ideality Harmonization Dynamization	1.1.3, 2.1.1, 2.2.3, 3.1.1, 3.1.4, 4.1.2, 4.2.1, 4.2.2,4.2.3, 5.1.1.1, 5.2.3, 5.4.1, 5.5.1	25,20,28,12

The table describes the instruments that get the tips how to come to these solutions from previous state of the system.

Like other tools of this kind, the suggested mapping does not pretend to be complete but suggests the recommended tools. The names and descriptions of inventive principles and standard solutions are omitted to save space.

5. Practical application

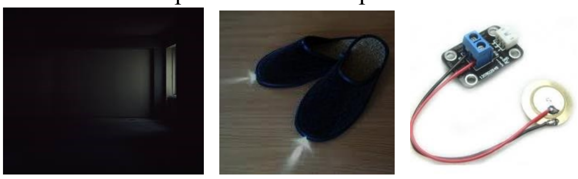
The suggested map of disadvantage overcoming tools was used in numerous educational courses and showed positive results. Our students were able to attribute particular problems to one or few of 30 typical DA after about just an hour of study. The use of the suggested principles and trends was available to beginners, right after learning corresponding tools. Standard solutions appeared not as easy in use, but in the basic (1-2 days) educational courses we did not even try to use them, as far as this instrument requires high enough qualification of a solver.

When explaining the procedure, we faced some common questions that students frequently asked. The discussions allowed students to better understand the essence of the inventive problems and, in fact, prepared them to learning next topics.

For example, a very frequent question concerns the choice of one of multiple disadvantages in the same system. For example, in the glasses they found three disadvantages: big size when transportation (#13), small distance of useful action (#17) and trivial shape (#16) – so, what to select? Our answer was: "*Which of them you consider the most harmful or uncomfortable?*", preparing them to the subsequent topic "Ideality".

Another situation. For an asphalt compactor, a student determined the disadvantage as "too small weight" that he could not find in Table 1 – but found the opposite term "high weight" (#8). Could he use it instead? Our answer was: "If small weight is a disadvantage, *don't you know how* to make the machine heavier? *Do you need new* *invention* for that?" After obvious answer "Of course not!", the students found a real disadvantage: "insufficient function" (#25). This procedure indirectly stimulated students to distinguish inventive problems from routine, easy-to-solve tasks and, therefore, to specify the real problems that include contradictions.

Now let us present one example of the students' work.



a **b** **c**

Fig. 1 Ideas of simple, cheap and always-with-you home night vision system
a: essence of problem (too dark room); **b:** use of the trend of completeness (adding a light source to an existing al-ways-with-you system); **c:** idea based on the principle #18 (use of mechanical vibration: switch of the light with under-floor/on-floor vibration sensor that detects waking-up).

The task was formulated as "to suggest idea of simple and cheap home night vision system that is always with you at night", with the physical contradiction (that was assumed although not sounded): *light should be bright to be visible, and it should be dim to allow sleeping*. The students attributed the disadvantage *of* the prototype system to the type 27 "Insufficient level of function". By using the instruments recommended for this type of DA they suggested several ideas; two of them are presented in Figure.

We have to note that, although this instrument was planned to use only in educational projects, in fact we also used it in our own projects as an auxiliary instrument. An example is presented in (Danilovsky & Ikovenko, 2014).

6. Conclusion

Our experience of teaching TRIZ in different countries demonstrates the critical need in much accelerating the basic courses of TRIZ. By analyzing possible causes of "long learning curve" problem, we came to a conclusion that most of existing educational programs are implicitly adapted to the specifics of Russian educational system and use some specific features of Russian mentality, which simplifies TRIZ education in Russia but complicates it in other countries and cultures. In particular, serious difficulties are permanently observed when teaching the concept of contradiction that is especially inconvenient in the Eastern countries.

To overcome this difficulty, we suggest the use of disadvantage as a key term, prior to learning the concept of TRIZ contradictions. Our reasoning is based on the strong relationship between disadvantage and contradiction as an outward manifestation and its internal cause. This relationship itself is well known in TRIZ, and it is well known that for inexperienced people, disadvantages are mostly much easier to formulate than contradictions.

However, practical use of this very basic concept in real-world TRIZ education required some additional instrumental support. As a supporting tool, we suggest a new classification of typical disadvantages (DA) accomplished with the "map" that connects each type of DA with particular instruments of classical TRIZ: principles, trends and standard solutions.

Basing the introductory course of TRIZ on the concept of disadvantage, instead of contradiction, considerably simplifies learning the above-mentioned tools of classical TRIZ (principles, trends and standard solutions) and does not cause psychological abruption by the students. By using this approach, the students are able to use these tools in their own practice from very beginning, without spending much time for learning the mentally "foreign" (for many of them) idea of contradictions.

Then, after students get some practical experience of the use of new instruments, it is much easier to explain them how these instruments work internally; this is a good time to teach them the concept of contradictions as a theoretical explanation of what they already can do in practice and why it works.

Thus, finally we get the same result (the students learn the concept of contradiction and try to use the instruments that help to overcome them), but without such undesirable effects as psychological abruption and long learning curve.

As a "side effect", the suggested method became effective in our own projects as well: it allowed saving some time when searching for the simplest solutions. An example of such solution is described above.

We believe that the suggested approach not only facilitates learning the classical TRIZ tools (trends, principles, standard solutions) but also allows better understanding of basic concepts of TRIZ.

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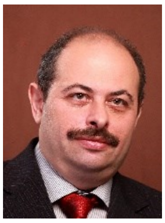

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