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Humor is Necessary for Intensification Learning Creative Technologies in Engineering Education

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Abstract *- The article reveals the possibilities of using joke and cartoon as didactic tools that are adequate to the goals of "mass-education" of teaching creative technologies, where the theory of solving inventive problems (TRIZ) is a prominent representative today. These forms of humor have a range of unique properties and are therefore suitable for teaching different categories of students creative thinking procedures at all levels of training and self-education. An original method has been created, the essence of which is to gradually transform an joke and caricature in the classroom from passive (illustrative-relaxation) didactic tools into active ones, which increase the motivation and success of students ' activities by increasing their instrumental knowledge and skills to change systems of any nature (this is knowledge of the meta-level-knowledge-transformation and system knowledge). Algorithmic procedures for using these forms of humor have been tested in the University environment and the post-graduate education system (including teacher training), as well as in business education (in industrial companies, research centers and laboratories). The effectiveness and efficiency of using these non-standard didactic tools has been confirmed*

Keywords: jokes, caricatures, innovations, creative technologies

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1. Introduction

In the past, creativity was the lot of a few people. However, in today's rapidly changing world, the development of creative technologies has become an urgent need for representatives of all professions. It has been 40 years since the appearance of the famous report "No Limits to Learning" to the club of Rome (Botkin, Elmandjra & Malitza, 1979), which put forward the concept of "innovative learning", according to which the education and development of a person should be "anticipating" (ahead) instead of the existing "lagging". It offered to train people to behave appropriately in the face of new situations, to anticipate the future, to assess the consequences of decisions made, and to actively participate in shaping the future. Thus, the problem of "massing" creativity has become sharply topical in the world.

Many people know the famous idea of the science fiction writer and inventor Arthur Charles Clarke that "any sufficiently developed technology is indistinguishable from magic". It is directly related to the field of modern engineering, which today is already similar to science fiction.

Among the existing methods of creating new ideas, the theory of inventive problem solving (TRIZ), which has become a developed science and technology, stands out. The extended abbreviation TRIZ-as a General theory of strong thinking (TRIZ-OTSM) - was proposed by the Creator of the theory – Heinrich Altschuller in 1986. Over the course of 70 years of development, TRIZ has significantly evolved its interdisciplinary tools, which are based on a system of General laws of the evolution of technical systems (Altshuller, 1979; Altshuller, Zlotin, Zusman, & Filatov, 1989). If you build a two-dimensional diagram in the coordinates "power (efficiency) of the method – "complexity") and place the main methods of searching for technical solutions in these coordinates, it becomes clear that TRIZ has the highest intellectual power (Fig. 1). However, some TRIZ tools are quite difficult to master and require a lot of effort.

Although TRIZ has already gone far beyond technology, it is its technical applications that currently have the greatest appeal. There is a standardization of the conceptual apparatus and technologies, which contributes to the "mass" development of TRIZ in the technosphere (Soushkov, 2014; Hiltmann, Thurnes, & Adunka, 2015). However, it should be noted that in the modern format (together with cost engineering and other developments) TRIZ today forms the contours of the future integral science of perfect thinking and activity, the foundations of which were laid by Tadeusz Kotarbinsky (Kotarbinsky, 1975). In fact, we are talking about a kind of " advanced praxeology "(as a theory of perfect activity), where an important element is the theory of strong thinking. In the bosom of the "TRIZ movement" today, there are even interpretations of TRIZ as "applied dialectics", because its tools are suitable for working in any socio-technical-economic and socio-cultural systems.

"Massing" the development of creative technologies based on TRIZ is a complex process. For their development, an innovative learning technology is needed, which must have effective didactic tools. They must be adequate to the diversity of the modern world and the complexity of creative technologies, but the main thing is to be able to reduce this complexity. After all, only simplification helps people understand the complex world. One of the" fathers "of Cybernetics, William Ross Ashby, constantly emphasized:"our goal is simplification." It is known that the Creator of the internationally recognized system of training in acting, who laid the Foundation of the modern science of theater – Konstantin Stanislavsky is the author of the famous phrase: "make the difficult simple, make the simple familiar, make the familiar pleasant." It has become a kind of guiding star for us in our research, because it almost directly suggests what the didactic means should be for implementing the "democratization of creativity".

Following the idea of Gianni Rodari that "the learning process should not proceed sullenly" (Rodari, 1978, p. 30), we made a logical assumption that non-standard didactic tools should be used when developing creative technologies (tools) based on TRIZ. That is why the purpose of our research was to identify the functional capabilities of humor tools, namely joke and caricature, as didactic tools for teaching technologies and tools for engineers ' creativity as future creators of the technosphere.

To achieve this goal, we solved the following tasks: 1) justify and provide convincing evidence of the correctness of the choice of these tools, as well as their adequacy to the problem being solved; 2) analyze and identify the range of functionality of joke and caricature, as bright forms of humor, in the implementation of didactic tasks of teaching creativity; 3) develop a methodology (algorithms) for using these tools in teaching different categories of students;4) conduct testing of the method, check and confirm the effectiveness of using these forms of humor.

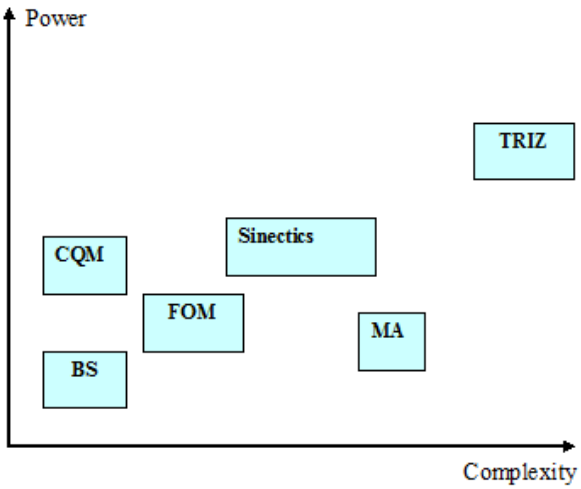

Figure 1. Comparison of the power of methods for creating new ideas (Tsurikov, 1991):

BS and CQM - methods of brainstorming and control questions; FOM and MA – focal objects and morphological analysis

2. Materials and methods

When performing its synthesizing role, education includes not only the transfer of knowledge ("ration"), but also the education of a spiritual style ("emotsio"), as well as the development of skills ("intuitio"). In view of this, our research involved a wide range of theories, concepts, and models: system analysis-synthesis (including the method of functional-cost analysis (FSA) of systems), intelligence modeling, and psychological concepts (including the Yerkes-Dodson law, and the flow theory of M. Chiksentmihayi), didactics in General and concepts of engineering pedagogy in particular, numerous theories and methods of creativity, theories and concepts of the funny and comic.

According to Paul MacDonald, humor has accompanied the training and development of people since ancient times, the oldest jokes date back to 1900 BC(!) (McDonald, 2013). However, the object of deep analysis of scientists – representatives of various Sciences humor became only in the XIX-XX centuries. Among them should be named A. Bergson, A. Schopenhauer, Z. Freud, W. fry, R. Martin, V. Y. Propp, A. N. Luka, and others (Fry & Salameh, 1993; Martin, 2007; Luk, 1977).

For many centuries, people have used trial and error to solve emerging problems and create innovations. In the last century, there was an "explosive" appearance of many methods of inventive creativity: "catalog" (F. Kunze, 1926); "brainstorming" (A. Osborn, 1942); "morphological analysis" (F. Zwicky, 1942); "Synectics" (V. Gordon, 1944); "control questions" (D. poya,1945; R. Crawford, 1954; S. Pearson, 1957, A. Osborn, 1964; T. Eyloart, 1969); "focal objects" (CH.whiting, 1958), etc. (Osborn, 1942; Zwicky, 1969; Gordon, 1961; Eiloart, 1969). However, many methods still used intuition, as well as iterating over

solutions to problems (Kudryavtsev, 1991). One of the pioneers in the field of creative research – Alex Osborne-even said: "Quantity, quantity and quantity again! That's the motto of the day."

An important stage in the development of the methodology of creativity and its technologization was the appearance in 1956 in the Soviet Union of the theory of solving inventive problems-TRIZ (Altshuller & Shapiro, 1956). Since the end of the 1980s, the international project "inventing machine"was launched. It began connecting the already well-developed TRIZ tools with computer equipment. As a result, a whole family of software products "computer aided thinking" appeared (Tsurikov, 1991).

Scientific and pedagogical communities of all countries of the world from the very beginning of the appearance of non-algorithmic methods of creativity actively used them in the training of future specialists, primarily engineers. On their basis, the creation of effective methods of training and development of students began. There was an active connection of research results of representatives of various scientific and artistic schools: philosophy, linguistics, psychophysiology, psychology, pedagogy, fine arts (theory of art systems), etc. (Yerkes & Dodson, 1908; Csikszentmihalyi, 1975; Kaloti, 1998; Murashkovsky, 2006; Murashkovsky, 2007). In the sphere of technical education and engineering creative pedagogy, scientific and pedagogical schools were formed in Yekaterinburg, Kazan, Krasnoyarsk, Moscow, Novosibirsk, Penza, Tomsk, and a number of other cities (vlaznev A. I., Zinovkina M. M., Kudryavtsev T. V., Stolyarov Yu.S., Novoselov S. A., and others). Many researchers and teachers used humorous tools for teaching TRIZ at different times: V. Gerasimov and S. Litvin (St. Petersburg-Boston), B. Zlotin and A. Zusman (Kishinev – Detroit), Yu. Tamberg (Veliky Novgorod), V. Urazaev (Kazan), V. Galetov (Chelyabinsk – Cheboksary), V. Likholetov (Chelyabinsk) and others (Valetov, 2014; Gerasimov, 2012; Kozhevnikova & Berezina, 2008; Litvin & Zlotin, 1987; Likholetov, 2000; Tymoshchuk, 1997; Urazaev, 2006; Urazaev, 2010).

3. The results of the study and their discussion

In our study, we proceeded from the postulate that in order to understand the rapidly changing world, modern man must be holistic and systematic. After all, without a person building a complete picture of the world, creativity is impossible. There are good Russian Proverbs on this score: "Go there, I don't know where" or "Don't go into the water without knowing the Ford").

3.1. Justification for choosing adequate didactic tools for teaching creativity

In engineering, when developing new objects or processes, the "technical task" for the design is usually formulated first. Let's try to create a similar "technical task" for promising didactic tools necessary for the development of technologies (tools) of creativity. Based on the logic of TRIZ, we formulate the task as a system of contradictions – a system of opposite and complementary requirements (Table 1).

Table 1. List of requirements for technology development tools creativity formulated in the form of contradictions

№	Statement of requirements
1	With these tools, the learner must learn a lot (+) and cannot learn a lot (–)
2	The tools should reflect the world that has been defined, that is, they should be subject-oriented (+) and metapredmetric, that is, methodological (–)
3	These tools should be focused on the feelings and emotions of the person, that is, be irrational (+) and be scientific and theoretical, that is, rational (–)
4	Means must be concrete – real (+) and abstract, i.e. generalized-ideal (–)
5	Funds must be individually oriented (+) and must be socially oriented, that is, general cultural (–)
6	The means must be natural – natural (+) and cannot be so, because we live in an artificial world (–)
7	The learning process should be learning (+) in its form and should not be learning as such (–), that is, it is about game learning

This list can obviously be expanded. Ideally, the full range of requirements should be formulated in all known pairs of philosophical categories: essence-phenomenon, content-form, whole-part, system-structure-element, individual-General, cause-effect, necessary-random, real-possible (real-ideal). However, in connection with the impossibility of achieving ideal (because, according to the exact aphorism prutkov "it is Impossible to grasp the immensity"), we will use the principle of trinitarizma ("uncertainty-complementarity-compatibility") in which to strive for certainty need not always (Barantsev, 2005, p. 16). A good reference point for us at this point is the well-known example of "limited rationality" from the history of decision-making, proposed by the Nobel laureate Herbert Simon (Simon, 1978).

We will perform a reflexive analysis of the list of requirements for the means of mastering creative technologies presented in Table 1. According to the first requirement, the student must know a lot (+) and cannot know a lot (–). At the same time, we have a restriction on resolving this contradiction in time and outside the "human"system. There is a ban on procrastination (you can not postpone training "for later"), and it can not be implemented by going to the super-system (outside of a specific person, i.e., in a group, community of people). As a result, this contradiction has only two ways to "remove" (or resolve), namely: 1) by changing the properties of the

"human" system itself, and 2) by switching to a subsystem. Understanding the implementation of the first method gives rise to the idea that human change must be accelerated. In other words, you need to learn how to change the state of human consciousness, because it is too slow (!). Thus, there is a requirement to intensify training. The second way to resolve the contradiction can be commented on by the thoughts of Heraclitus ("multi-Knowledge does not teach the mind"), as well as Aeschylus ("Wise – who knows what is necessary, and not much"). Thus, the second method leads us to the need to select the" necessary "knowledge from the"many".

Consider the second requirement (see Table 1). The established traditions of education Orient teachers to the development of students already opredmechennogo ("grounded") knowledge, while the innovation of education requires raspredmechennogo knowledge. It is necessary to create new specific tasks and original solutions. Therefore, knowledge should be subject-oriented (+) and should not be subject –oriented (-). In other words, knowledge must be substantive (+) and meta-subject, that is, methodological (–). In the practice of education, this contradiction is most often resolved in time: first, a theory is given, which is later fixed by exercises. It is no accident that the Canon in the history of pedagogy was the thought of I. Kant (it was repeated later by G. Kirchhoff and L. Boltzmann): "there Is nothing more practical than a good theory." It is opposite and at the same time complementary to the thought of Newton: "in the study of Sciences, examples are more useful than rules."

However, this is not enough. The need to resolve the contradictions by transition to super-system knowledge can be found in many educators and teachers, in particular: a) G. Lichtenberg ("Who knows nothing but chemistry, and he knows it's not enough"); b) S. Hesse ("...the task of learning is learning the method of science..., all individual knowledge is ... for the beginning of a deeper lying behind what was being taught..." (Hessen, 1995, p. 244-245); V. Davydov's concept of gradual transition to meaningful generalizations through empirical generalization in learning (Davydov, 1972), etc.

The third requirement shown in Table 1, is due to the unity of the sensual and rational in man ("emotsio" and "ratio"). Curiously, in the Orphic cult of ancient Greece, the word "theoria" meant " a state of passionate religious contemplation, where the viewer was identified with the suffering God, died his death, and was reborn with him. When the Pythagoreans transformed religious fervor into intellectual fervor, and the ecstasy of ritual into the ecstasy of discovery, theoria gradually acquired a modern meaning" (Orlov, 1992, p. 98). In the light of these considerations, we see the formulation of the third contradiction as follows. When teaching creative technologies, knowledge must be sensual, emotional (otherwise – irrational) (+) and must be scientific and theoretical (rational) (-).

The choice of a way to resolve the contradiction by changing the properties of the system itself is due to the commonality of emotional and rational principles in the phylogenetic aspect (this was shown above on the example of the transformation of the concept of "theoria" in the Greeks). This is why we must recognize that emotional intelligence in the modern sense has been key to human survival since prehistoric times.

The wording of the fourth contradiction given in Table 1, requires that didactic means ensure unity of concreteness of form (+) and abstraction (or generality) of content (–). Methods for resolving this contradiction in relation to engineering education are given in sufficient detail in (Godlevskaya & Likholetov, 2013).

The fifth requirement (see Table 1) shows the need to provide the process of teaching creativity with means that allow students to transfer knowledge not only in an individual-oriented (+) way, but also in a socially-oriented or General cultural (–) way. A quote from the philosophical work of K. Svasyan is relevant here: "the Misadventures of science began when it was separated from art, erasing from it everything personal and so far incomprehensible" (Svasyan, 2002, p. 11). On its basis, we have formed the idea that the desired adequate means of mastering creative technologies are located in the area of intersection of individual and social psychology, which has not yet been sufficiently studied.

Let's comment on the sixth requirement given in Table 1. At the time of J. Comenius and Rousseau gave birth to the two basic understandings of the principle of natural law in education. They indicated, on the one hand, the need to take into account the laws of the surrounding external nature, and on the other hand, the internal nature of man. Many years have passed since then. However, as we know, "man" in Sanskrit means "disciple of time". To date, the external environment has changed very much. It has become largely artificial. Philosophers discuss the problem of artificial human anastrophe. For him, the artificial environment is natural (Pavlenko, 2010). The modern life of society (completely "stitched" by television, the Internet and social networks) is actually on the verge of reality and virtuality. In this regard, the discussed means of mastering creative technologies should "grasp" both reality and ideality.

Let's explain the seventh requirement given in Table 1. According to the conclusions of many researchers, in particular K. Dunker, life is a stream of solved problems, most of which are solved unconsciously (Likholetov & Aliukov, 2019, p. 1606). It is no accident that in the last half-century, interest in problem-based learning has become more relevant. The problematic nature brings learning closer to life, but increasing the level of complexity of the tasks to be solved, according to the Yerkes-Dodson law (Yerkes & Dodson, 1908), requires, oddly enough, not increasing at all, but, on the contrary, reducing the optimal level of motivation of students. This phenomenon has been well studied and refined recently with regard to the efficiency and effectiveness of solving problems depending on their level of complexity (Gorbatkov, 2009; Sevost'yanov, Gainanov & Lisitskaya, 2014). In psychological terms, the effects of the Yerkes-Dodson law "intersect" with the well-

known flow theory of M. Chiksentmihaya (Csikszentmihalyi, 1975; Voiskunsky & Smyslova, 2002), according to which, if there are weak problem-solving skills, a person experiences fear when encountering a complex problem, and when meeting simple problems with medium or strong skills for solving them, a person is simply bored. The comfort zone in a person's life lies between boredom and anxiety. Games, entertainment, and sports give a person a sense of "flow". It is not difficult to conclude from this that learning becomes a game. However, everything needs a measure. For example, noting the problematic direction of its episodic course, S. Hesse pointed to the need to prevent "degeneration", first, by providing a balance of elements "wonderful" and "problem" (departure from "entertaining teaching"), and, second, the balance of the "point system" and "passionate". According to S. Hessen, the failures of I. Pestalozzi were associated with an excessive preponderance of the first over the second (Hessen, 1995, p. 287).

3.2. Identification and analysis of the functionality of an joke and caricature in the implementation of didactic tasks of teaching creative technologies

Today, at all levels of education (from school to colleges and universities, as well as in business consulting and retraining), there is a great interest in using various forms of humor as non-standard didactic tools. It is no accident that scientists of many Sciences are engaged in research of humor: linguists, cultural scientists, philosophers, sociologists, marketers, engineers, teachers, psychologists, doctors, etc.

According to the works of physiologist Pavel Simonov (Simonov, 1981), humor is necessary for a person to maintain flexibility of thinking, "preventive armament" - readiness for effective behavior in completely new situations. The same goal is pursued by training. It is important that humor always helps to discover new things: the inconsistency of close phenomena or the similarity of distant, unexpected qualities in the familiar. Therefore, Arthur Schopenhauer considered humor an integral part of the theory of knowledge. He even thought that to laugh was to understand the object, its essence. To do this, he developed the "theory of the absurd". Laughter on it arises due to the recognition of the absurd, awareness of the discrepancy between the concept and the real object.

Humor, as a kind of creativity, is itself a special way of knowing the world. Based more on intuition than logic, humor helps to convey a complete piece of reality, using a minimum of means. This is a kind of "hyperlinks" to already known facts, grouped in an unexpected order. For example, it takes more time and words to explain an joke than just telling it. Thus, humor is a unique means of transmitting experience. It is no accident that the biblical Wisdom of God in Hebrew sounds like "Hochma" (Stolovich, 1999, p. 244).

According to the founder of gelotology (the science of laughter), neurologist William fry, the number of antibodies in the blood increases during laughter. At the same time, almost a third (!) increases the release of endorphins (happiness hormones) and decreases the level of cortisol and adrenaline (stress hormones) (Fry & Salameh, 1993).

Reviews of humor literature are published regularly (Musiychuk, 2016). For example, the study of humor is active in linguistics (Kulinich, 1999). They give good results. Thus, the competent use of jokes when learning foreign languages allows students to "swim without a Board" after a while (Frank, 2016), which "echoes" the effect of the "Sliding" method of Professor V. Votinov.

However, the problem of widespread use of effective means of humor in pedagogical practice rests with the teachers themselves (Tamberg, 2005). Unfortunately, only 26% of teachers have a sense of humor. 62% of teachers partially possess it, and 12% of them do not have a sense of humor at all. Only half of the teachers have an optimistic attitude, and many are dissatisfied and even despondent, which, as we know, is a mortal sin.

In the course of learning through humor, you can implement a very wide range of functions, namely: 1) activate attention; 2) illustrate – use as an example; 3) motivate – encourage certain actions; 4) use as a rationing tool – in the mode of receiving feedback and implementing group sanctions; 5) provide relaxation – promote attention switching and rest; 6) test students – use humor in the diagnostic mode (Olekhnovich & Kostitsyn, 2006). Next, we denote these functions, respectively, with letters: A, I, M, N, R, T.

Joke and caricature are the most common means of humor in the system of teaching TRIZ tools and cost engineering (in Russia it is called functional cost analysis). The reason for attention to them is the unique properties of these forms of humor (Table 2).

These properties are very universal and provide the suitability of these forms of humor for the purposes of training a wide variety of categories of people, which is combined with the concept of efficiency. According to the idea of Professor A.V. Ptushenko, efficiency is "an indicator of the degree of fitness of the system to solve a certain task in a certain situation" (Ptushenko, 2004, p. 27).

Usually, an joke is a humorous text of small form, which translates the recipient's state from the usual one to the state of "game activity, otherwise the perception of comicality would be incomplete" (Lotman, 1998). Although the world publishes a huge number of collections of jokes every year, there are many humor sites on the Internet, but the most popular way to transmit them is traditional oral. Jokes are objects of analysis in many Sciences, but their psychological perception and social functions are still poorly understood.

Caricature, as a form of graphic humor, is directly linked by artists to invention (Lozhko & Bogorad, 2009). As a specific artistic system, it creates what is difficult to do by other means. Like impossibilism (the product of which is the creation of pseudogeometric figures with mysterious topological properties), these constructions in the field of vision correspond to logical paradoxes for the mind. Their

elements perform two or more impossible functions, and they have opposite properties. In this regard, " ... the language of fine art is another natural tool that, along with the usual language that has rules for establishing a correlation between intuition, emotions, and illusions, frees us from the rationalistic Aristotelian assumption of tertium non datur (lat. - the third is not given)" (Kaloti, 1998, p. 68).

Table 2. Properties of joke and caricature that are important for learning

Sign (property)	Features of manifestation in forms: joke's	caricatures
Psychological comfort in the perception	The usual form of presenting information. Understandable by ear and visually. Familiar to people since childhood. It creates an expectation of play, entertainment, and fun. It has a high imagery and emotionality	
Ultimate short (compactness)	The effect is generated by one sentence ("one-line jokes") or two ("two-line jokes"). In the second case, the first sentence is an incentive for the manifestation of comicality in the second sentence-the culmination of the comic microtext	Convolution (no extra details), maximum convolution of colors. Often it's just a black and white drawing
Ambiguity of perception	The multiplicity of functions (meanings) sets the ambiguity of perception and understanding. Allegory. Animals, plants, and non-living objects are voiced and displayed, but these are people and connections of social objects. Metaphors create a concrete image of abstract concepts and allow different interpretations of real messages	
Surprise (novelty)	Subjective novelty is caused by the need to analyze linguistic or artistic systems that seem to be known in form. But it's not that simple	
Presence of a conflict	The conflict is aggravated. There is a pronounced conflict between the elements of the system. Broken (not created) the balance of communication between the elements of the system, which corresponds to the picture of real life	

As you know, more than 70% of information comes to a person through the visual channel. Therefore, caricature as a visual system with many meanings is also unique for learning. It doesn't have a lot of details, it's symbolic. This connects it with hieroglyphic writing. Hieroglyphs connect the language of art with natural language. For example, in Japanese and Chinese, there is no distinction between singular and plural, there is no gender category, and verbs do not have a person and number category. The ideographic character of hieroglyphic writing gives each sign its own meaning, so it can be semantically perceived outside of context. The sign always remains itself and at the same time dissolves in the General undifferentiated unity, meaning in the limit everything that is (Steiner, 1987).

3.3. Novelty and methodological features of the use of humor tools in training different categories of representatives of the engineering field

For more than 20 years, joke and caricature have been actively used by us as didactic tools for teaching various categories of students how to create innovations based on TRIZ (Table 3).

For these purposes, original textbooks have been published and tested (Likholetov, 2000). They are very popular in the Russian Internet sector. The first of these (Likholetov, 2000) a sequence illustrating the joke of the conceptual apparatus of FSA and TRIZ is accepted as follows: first come the basic concepts, then system ways (methods) of solving technical contradictions, and after they are used to illustrate basic laws of development of systems. In the second manual (Zwicky, 1969), we present 252 cartoons "without words", the thematic sequence of their reflection of the system of concepts of TRIZ and FSA is adopted the same as in the manual (Osborn, 1942). Methodological features of the use of these means of humor are described in detail and protected in the dissertation work of one of the authors of this article (Likholetov, 2002).

They have a step-by-step and multi-functional mode of using humor (from simple to complex). Means are gradually transformed from passive (illustrative and relaxation) to active. For this purpose, at the first stage of training (or self-training), the mode of using joke and caricature is focused on the formation of traditional passive forms of knowledge, that is, knowledge-acquaintances and knowledge-copies. At the next stages, the students 'knowledge-skills, knowledge-skills are being formed, and after that, their kind of "negation", that is, knowledge of the meta-level.

Thus, as students learn the tools of TRIZ, they form knowledge-transformations and knowledge of the system type. They can be called "knowledge of knowledge", that is, knowledge of how to make new knowledge. In the field of invention, this is similar to the class of "inventions for use". The process of forming these levels of knowledge is shown in the paper (Godlevskaya, Likholetov & Aliukov, 2019). This is a non-obvious use of known inventive solutions (methods, devices, substances, strains) for an unexpectedly new purpose (in areas very far from traditional). And in the field of modern innovations, this trend is associated with the transfer of knowledge and technology.

In the University environment, didactic tools based on humor were used and are now used for training future

specialists in engineering, innovation, Economics, management, law, and computer science at universities: South Ural state University (formerly Chelyabinsk state technical University), Chelyabinsk Agroengineering University, and the Chelyabinsk branch of the Russian presidential Academy of Sciences.

Table 3. Modes of using humor when learning TRIZ and cost engineering tools

№	Type of training	Didactic tools	Function codes for the use of funds*					
			A	I	M	N	P	T
1	Education in colleges and universities	Joke	●	●	●	●	●	
		Caricature	●	●			●	●
2	Postgraduate (advanced training)	Joke	●	●			●	
		Caricature	●	●			●	●
3	Training in companies	Joke	●	●			●	
		Caricature	●	●			●	●

* Accepted abbreviations: A-activation of attention; I and M - modes of illustration and motivation; N - for normalization of learning activity; P and T - modes of relaxation and testing

In 1994-2001, the accumulated experience in the inventing machine project was used for postgraduate training at the faculty of Economics and entrepreneurship of the Chelyabinsk State Technical University (SUSU). The model was created distance learning for a period of 2.5 years. The block of methodological and information-analytical disciplines formed on the basis of TRIZ, FSA (cost engineering) and experimental planning ("Development of creative imagination", "problem-setting Technology", "system Analysis and problem solving", "system Modeling", "Computer technologies for supporting thinking" (using "inventing machine" products: IM-FSA, IM-techniques, IM-standards, IM-effects, IM-application) was combined with the block of economic and management disciplines. On this basis, post-graduate training of specialists on the basis of higher technical education in the specialty "Analysis and problem solving in socio-technical and economic systems" within the specialty "Management"was implemented. Out of the initial 8 groups of listeners, 39 managers and analysts were released. Today, they have become top managers of the largest companies in the country and the region, commercial banks, and have joined the leadership of regional ministries. As a result of this work, methodological support for the cycle of creative disciplines adapted to University programs was created, which later allowed expanding the zone of influence of TRIZ and FSA technologies on a number of non-technical specialties of the University.

Since the late 90's, these developments have been used to improve the skills of teachers of all faculties of SUSU, as well as other universities in Chelyabinsk (state and pedagogical universities, higher military aviation school of navigators) (Likholetov & Shmakov, 2016). Since 2008 (according to the Order of Federal education Agency from 10.12.2007 No. 2270 through the Institute of additional professional education South Ural state University (as basic institution) in the us for 7 years implemented a program of training of teachers of other universities of the country ("line universities") in the name of "the Possible use of the potential of TRIZ and the theory of creative personality development (Russian acronym-trtl) in the modernization of University disciplines" in "Innovation" (72 hour). The geography of the audience was very wide-from St. Petersburg and Moscow to Yuzhno-Sakhalinsk. The degree of their satisfaction can be determined by a number of reviews posted on the Internet (Sidorov, 2016).

Since the early 1990s, joke and caricature have been used by US when developing tools for TRIZ and cost engineering not only in universities and colleges, but also among scientific and technical workers and employees of industrial companies: 1) in Russia (Ural house of scientific and technical propaganda, engineering center "teplostroy", trust "Vostokkhimzaschita" (Chelyabinsk), "AVTOVAZ" (Tolyatti), "KRANEKS" (Ivanovo), "Uralmotoprom" (Irbit), "yuzhuralmash (Orsk), etc.; 2) in Ukraine (Ukrainian house of scientific and technical propaganda, Kiev Institute of civil engineering), etc.; in Kazakhstan (rudnensky industrial Institute, "Sokolov-Sarbay mining and production Association" (Rudny). The duration of training seminars in the industry was usually 2-3 weeks.

In recent years (starting from 2004-2005), we have conducted a number of introductory training seminars on TRIZ (lasting from 2 to 5 days) in industrial companies and research institutes of the southern Urals, which used methods based on humorous means. Here are the names of these companies and their production profile: MMK – Magnitogorsk iron and steel works (Magnitogorsk), RosNITI-Russian research Institute of the pipe industry (Chelyabinsk) - metallurgy; JSC "Teplopribor", JSC "plant " Device", JSC Chelyabinsk watch factory "Lightning" (Chelyabinsk) - instrument making; LLC "IRON KING" (Verkhneuralsk) - sports equipment factory.

Keeping in mind the effect of the Yerkes-Dodson law (on the level of optimal motivation), during all the classes held in various classrooms, we carried out a moderate dosage of humor (see the above thought of S. Hessen about "entertaining learning"). At the same time, we also followed the recommendations of R. Martin that when using humor to help students memorize educational materials, it is necessary to be careful, that is, to use humor gradually, linking it with key concepts, and not secondary information (Martin, 2007, pp. 406-407). By the way, we also confirmed the opinion of R. Martin and other researchers that the inclusion of humorous questions in test tests helps to

reduce test anxiety and improve test results, as well as the fact that funny drawings increase the ability of students to learn educational information.

At the same time, the novelty of our approaches to teaching creative tools is that we have gone a little further in using humor than the mode of illustrating and providing relaxation. We use the caricature for in-depth testing of persons studying the basic technological tools of TRIZ. See Table 4. We provide an illustration of the procedure for non-standard knowledge qualimetry, that is, evaluating the diagnostic capabilities of students ' knowledge levels when using caricature drawings.

Table 4. Test assessment of levels of tasks on the cartoon

Tasks for students at the boundary or final control of knowledge	Test levels and their nature			
	1	**2**	**3**	**4**
	«recognition»: Op-identification; RA-distinction; CL-classification; Ot-open test; Po-sequence test	«playback»: Sub-substitution; CT-design test; TK-typical task; TP-typical process	«application»: Zprim - tasks for applying knowledge; T – tests of the stairs; KZ-complex tasks	«transformation» Zpr-conversion tasks (migrating and creating systems)
1	2	3	4	5
Name the system in the figure	Op, RA, CL		Zprim	
Describe the composition of the system	Op, RA, Πo	CT, TP	Zprim	
Name supersystems	Op, RA, CL, Ot		Zprim	
Description of the link	Op, RA, CL, Ot		Zprim	
To formulate a function	Oт, Po	CT	Zprim, T	
Identify conflicting information pair (s) of elements	RA, Ot		Zprim	
Describe the conflict	Op, RA, CL, Ot		Zprim, T	
Restore the contradiction that led to conflict	Ot, Po	CT, TK, TP	Zprim	Zpr
Diagnose ways to resolve a contradiction	Op, RA, CL, Ot	TP	Zprim, T, KZ	Zpr
Diagnose resources involved in resolving a conflict	Op, RA, CL, Ot		Zprim, T, KZ	
Describe a system that is more ideal than the one shown in the figure	Ot	TP	Zprim, T	Zpr

Only at first glance, the essence of these tasks for students (or students of advanced training courses) in terms of the composition of questions does not differ from the system of questions of a simple picture story for schoolchildren (Murashkovska & Valyums, 1995). However, they are directly focused on identifying the level of development of basic TRIZ and FSA tools by students, such as:

- G.S. Altshuller's multi-screen thinking scheme, which includes nine screens along the axes of space and hierarchy of systems (subsystem-system-supersystem) and time (past-present-future);
- structural and functional analysis (for example, function formulation rules);
- identification of conflict models as undesirable effects (this point is described in detail in (Likholetov & Aliukov, 2019, p. 1613);
- formulations of contradictions;
- formulation of ways to resolve contradictions;
- analysis of resources (as a means of resolving contradictions);
- concepts of ideality (ideal final result).

At the same time, the logic of the subjects ' reasoning when testing by caricature (see Table 4), to a certain extent, is similar to the sequence of steps in solving problems using the algorithm for solving inventive problems (ARIZ).

3.4. Examples of the use of humor in learning and the results of learning creative technologies

Currently, a number of system modeling methodologists see the use of multi-model and model games as a perspective for describing complex systems. They include not only a set of complementary models that reflect qualitatively different blocks of a higher-level super-system, but also a set of opposite models of the same super-system block (Novik & Pegova, 1986). We believe that the means of joke and caricature under study can be attributed to such systems –

opposing (or playing) models. After all, representing the product of combining systems and anti-systems from the TRIZ perspective, they do not reflect the unity of opposites in statics and dynamics (Table 5, Figures 2-5).

From the world-famous study of Y. Heysingi "the man who plays" directly follows the idea that the entire culture of mankind is obliged to the game (Huizinga, 1997). Developing this idea in the direction of system modeling, it is not difficult to understand that the means of humor considered by us are quite adequate, but at the same time they reflect (model) all the realities of human life in a compact, extremely compressed form.

Table 5. Example of using an joke as an activation tool attention (A), illustration (S), relaxation (P) when teaching students tools for resolving contradictions

Method	Essence	Example
1	2	3
The way to separate the contradiction in space		
«Nesting dolls»	One object is placed inside another	The man in the tram: - Allow me to put an aquarium on the seat. "I'm sorry, but where do you have it?" - In the stomach: 5 liters of beer and 2 herring
Ways to divide contradictions in time		
«Breakthrough 's»	Overcome dangerous stages of the process at high speed	In office a man asks doctor: - Doctor, why does someone all ignore me?. – Next...
Waste and regeneration of parts	Completed the assignment, becoming unnecessary part is discarded or changed	A fight in a saloon in the Wild West in the United States. The bartender grabs a drunk cowboy by the collar: "Why did you shoot the pianist?" He replies: - Well, write it in my bill
Ways to resolve the conflict by changing the system properties		
Discoloration	Change the color of an object or environment	The husband complains to the wife: - All evening on the TV screen one fire! The wife answers: - it is necessary to drink less. The TV is being repaired, and you're looking into the fireplace
Ways to resolve a contradiction by switching to a super system		
Turn harm to good	Use harmful effects to get useful ones	Before the first jump, the novice asks an experienced skydiver: - What if the parachute does not open? He replies: - You then will not need to fold it!
Ways to resolve the contradiction by switching to the subsystem		
Crushings	Divide an object into independent parts	The wife asks her husband: - What do you love about me: my beautiful face or luxurious body? The husband responds: "Your sense of humor."
Ways to resolve the contradiction by switching to an alternative system		
Universalities	The object performs several different functions	"Please make me a suit, but take my son's measurements!" "Why?" - Because he will wear it after me.
Ways to resolve the contradiction by switching to the anti-system		
Preliminary anti-action	In advance, make changes to the object that are the opposite of undesirable ones	– Why did you try to escape from prison? – I wanted to get married!" – You have a strange idea of freedom."

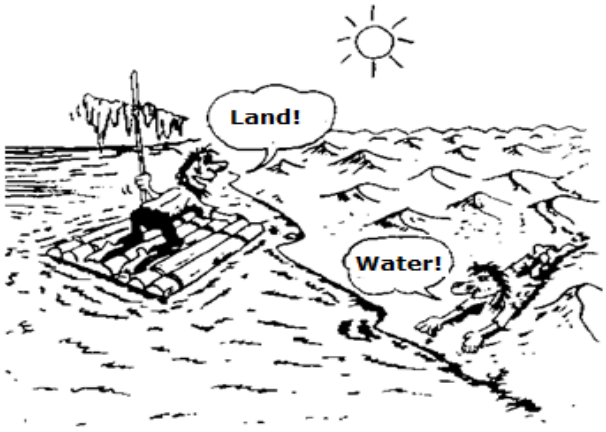

Figure 2. An example that reflects the "game" of contradictions: here "water is not water", "earth is not earth"

Figure 3. An example illustrating the method of resolving a contradiction in TRIZ is "splitting" (divide object into independent parts)

Figure 4. An example illustrating the method of resolving a contradiction in the TRIZ-method "copying

In our opinion, the cartoons shown in Figures 6 and 7 below reflect the effect of the law of uneven development of parts of the system, as well as the transition of systems to the micro level. According to the basic works on TRIZ, "in

the development of technical systems in accordance with the laws of dialectics, there is an alternation of stages of quantitative growth and qualitative jumps. In the process of quantitative growth, as a result of uneven development of technical system characteristics, contradictions appear" denominator (Altshuller, Zlotin, Zusman & Filatov, 1989, p. 35).

This leads to a logical conclusion that the means of humor are promising didactic tools for the implementation of the desired model games in the processes of learning and self-education (Table 6). and then change the production-attraction (P-A) trips to origin-destination (O-D) trips. Once a student group misses any of the steps, the assignment results would be inaccurate. Figure 5 below shows the assignment results of the groups

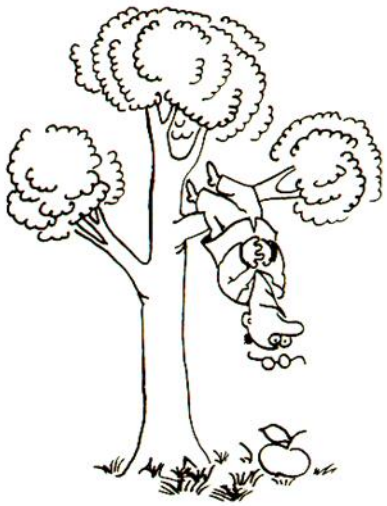

Figure 5. An example illustrating the method of resolving a contradiction in TRIZ-the "opposite" method

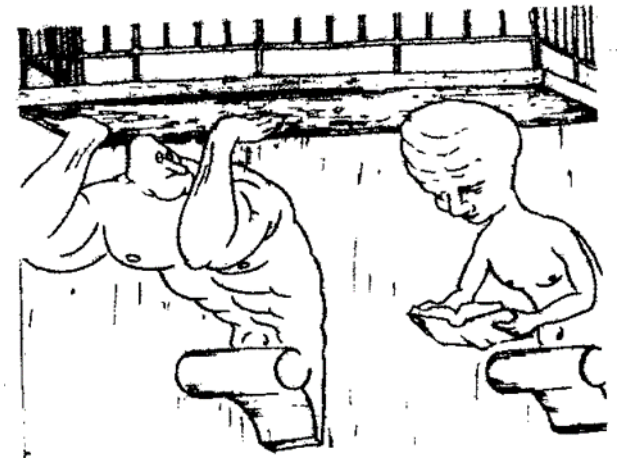

Figure 6. Illustration of the manifestation of the law of uneven development of parts of the system

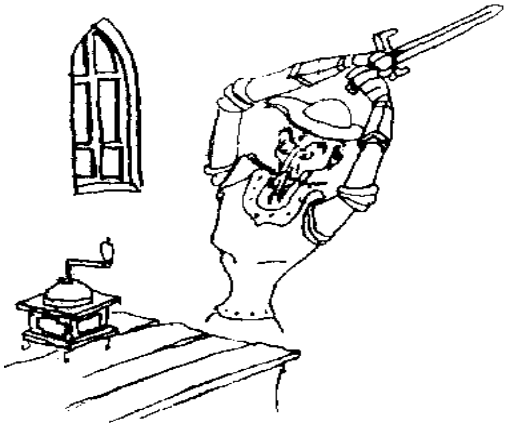

Figure 7. Illustration of the law of transition of technical systems to the micro level in the process of its development

Let us explain that the law of transition of technical systems to the micro level is interpreted in TRIZ as follows. In the logic of the development of technical systems, you can clearly see signs of increasing use of the deep levels of the structure of matter (matter) and various fields as they evolve. The analysis of the patent Fund allows us to identify a number of these levels of the structure of systems and the types of connections between them, as well as the applied effects and phenomena: 1) the macro level (gears, levers); 2) polysystems of elements with simple geometry (sets of sheets, cables); 3) polysystems made of dispersed elements (powders, emulsions,suspensions); 4) systems that use effects related to the structure of substances (supramolecular level); 5) systems that use molecular phenomena (polymerization, catalysis); 6) systems that use atomic phenomena; 7) systems that use the action of different fields (heat, electromagnetic interactions), etc. instead of substances denominator (Altshuller, Zlotin, Zusman & Filatov, 1989, pp. 59-60).

In the life of modern society, the law of transition to the microlevel in computer technology is clearly visible in the achievements of microelectronics, and in the biomedical field-in cell engineering and cloning of organisms. Mastering the level of principles and laws of system development helps to form skills for creating new ideas in the process of such "advanced" training, even in completely new areas for students. For example, it happened when collecting materials for a manual on caricature (Likholetov, 2000) with one of V. V. Likholetov's assistants – R. D. Yusupov - a student of the architectural and construction faculty of SUSU. Picking up caricatures from collections of caricatures, he began to design caricature themes on his own. What came out of this can be seen in the following illustrations (Figures 8-10).

Figure 8. The example of a humorous action on an object that is materially absent is the shadow of a man on the executioner's block

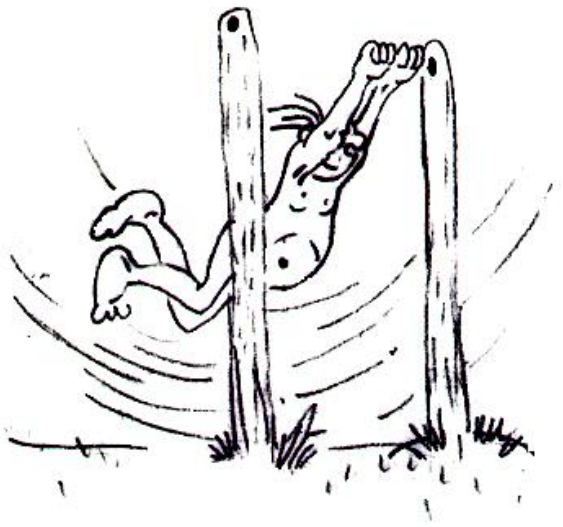

Figure 9. The example where there clearly is no functional need for an object, but its function is performed

Working with cartoon artists N. Fasina (Figure 8) and M. Vakhrin (Figure 9), where phantom objects (missing) but performing their functions (shadow on the block, missing horizontal bar) are actively exploited, this student-future civil engineer came up with a very good idea of his own caricature, clearly illustrating the ideal system. In this caricature, there is a sculpture that does not exist, but there is a shadow of it. This is shown below in Figure 10.

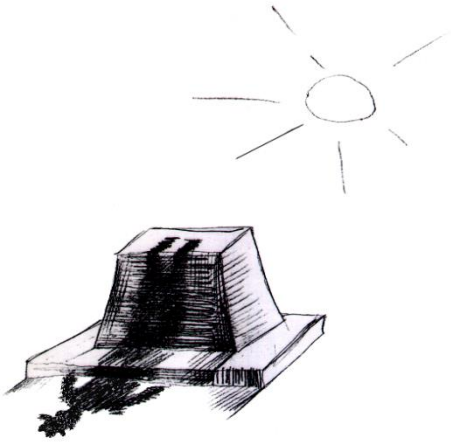

Figure 10. One of the examples of students ' creativity is "going out" on an independent mode of creating ideas and implementing them in a humorous way

At the end of the work on the caricature manual (Likholetov, 2000) the question of its review was considered. The reviewer was N. F. Chernyshev, a member of the Union of artists of UNESCO, a member of the European Association of cartoonists and a winner of more than 20 international competitions. Since 2010, he has been one of the top 100 cartoonists in the world. more

than 50 of his works are decorated in private museums and galleries around the world (Chernyshov, 2016). After getting acquainted with the content of our manual, he began to use it in the work of the club of cartoonists "Cranberry", which he created in 1985 and still operates today, where he teaches children (Gainullin, 2015).

According to his own admission, the intensity of the emergence of new ideas even for him, as a recognized master of drawing, increased several times (up to 4-7 hours against a week earlier-before getting acquainted with the TRIZ tools).

Table 6. Examples of humorous action illustrations some laws of development of technical systems

Law	Interpretation of the entity	Example in the form of a joke
Improving the degree of ideality	The development of technical systems is an increase in their ideality. Formula: I = F/Z →∞, where F is the useful functions of the system, Z is the cost of implementing useful functions. Especially intensive is the increase in ideality while simultaneously increasing the numerator and reducing the denominator (Altshuller, Zlotin, Zusman & Filatov, 1989. pp. 21, 41)	– What is maximum information with minimum costs? - It's a miniskirt!
S-shaped development	Another name-the law of the system's life cycle-is derived from the form of a curve that reflects the stages of the system's life in the coordinates of its main parameters (vertically) and "age" (horizontally). Technical systems, like living systems, are born, pass through the stages of childhood, become Mature, age, and die. They are replaced by the following denominator (Altshuller, Zlotin, Zusman & Filatov, 1989. pp. 24-33)	A journalist interviews a Hollywood movie star: - Where did you meet your sixth husband? – On a hunting trip where he shot my fifth husband.
Deployment-collapse	Improving the ideality of technical systems in their development comes first by deploying, i.e. increasing the number and quality of useful functions performed. The system gets complicated. Then comes the collapse, the system it becomes easier to maintain or increase the number and quality of useful functions denominator (Altshuller, Zlotin, Zusman & Filatov, 1989. p. 51)	The reporter asked Jack London: "do you like to celebrate your birthday?" The man answered him: - I love, but not my own, but my friends.
Alignment and misalignment	At the first stages of development of technical systems, the system and its subsystems are coordinated with each other and with the super-system to ensure effective functioning. In the next stages, there is a misalignment – changing individual parameters in order to obtain an additional useful effect. The final stage in the development cycle is dynamic coordination-mismatch, in other words-self-management or adaptation denominator (Altshuller, Zlotin, Zusman & Filatov, 1989, pp. 62-63)	The reporter asked an elderly lady who had lived all her life near the railway: "Lady, has the proximity of the road affected your health?" She said, " Yes-Yes-Yes, Yes-Yes-Yes, Yes-Yes-Yes, Yes-Yes-Yes, Yes…

The authors Express their sincere gratitude to Nikolai Chernyshev – President of the club of caricaturists "Cranberry" made them useful advice, support and approbation of methods of teaching technology of creativity, I wish him and his students new victories in international festivals and competitions of humorous illustration, and the club already more than a thousand (!)

4. Conclusion

Joke and caricature as a means of humor have a number of unique properties, so they must be used to intensify the process of training future engineers. They well reflect the unity of opposites in statics and dynamics, so they can serve as effective didactic tools for creating game situations in learning and self-education. Since the use of humor turns learning into a game, the development of creative tools is much faster. Training becomes comfortable and enjoyable, as a result, the speed of mastering new training materials increases, and the strength of skills and their effectiveness increases.

These forms of humor allow you to implement a wide range of functions. The compactness and imagery, universality and internationality of these tools are adequate to the complexity of the modern world. At the same time, humor reduces the complexity of creative technologies and makes them routine. Conditions are being created for the "democratization of creativity". At the same time, humor is not only a means, but also a goal of mastering creative thinking technologies. The output of students to independently generate ideas for jokes or caricature plots is a direct proof of achieving this goal.

The method of gradual transformation of an joke and caricature from passive (or illustrative) didactic means to active means, in essence, "extraction" of the functional potential hidden in them. It reflects the logic of moving through a cascade of functions – the main function, then additional functions, and then hidden functions. That is why the mode of these forms of humor in the process of learning (as well as self-education) is important to focus on the gradual ascent from the simplest skills of the

reproductive type to the productive ones, which indicate the formation of active forms of thinking. "Mass production" of creative technologies will increase the General culture of future engineers and thus create conditions for preventing a large number of man-made disasters and help reduce risks in today's complex world.

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