LEARNING OF TECHNOLOGIES: ROAD FROM NON-FORMAL EMPIRICAL DESCRIPTIONS TO FORMAL MATHEMATICAL STUDY

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Abstract. Three basic questions in the knowledge of Nature are known. They are: what, how and why. The answers to them are different and yet, closely tied up with each other. The answer to the question "what" is the industrial area or the area of technique. The answer to the question "how" is the field of technologies. The answer to the last question "why" can be given by natural philosophy and theology. The historical sequence of the study of these questions is what, how, why. The study of the answers to the second question or the study of technologies started in the last decades of the XVII century in Germany. At the period of approximately 250 years ago the technologies were studied only empirically. The system of non-formal technological laws was built at this period. It was only a pre-research study of formal mathematical methods. Over the last years some fundamental equations describing general properties of technologies were written. Therefore, it is possible to start with the study of the main philosophical problems of the matter transformation. The generation of terms and concepts was studied. The best terms reflecting the modern situation in the field of production technologies are introduced in this work. Some basic ideas devoted to classification of production technologies and provision of services are introduced as well. The influence on errors of measured objects' properties was found as one of the most valuable in the field of preparing materials, goods and service with predicted properties. A graduated expert in technology problems has to know the historical background. He or she must know the principles which enable to divide the whole technological area into several parts: the part of industrial production processes, the part of social receipts and the intermediate part of action impacts on the individual. The main mathematical problems, which are necessary for a qualified expert in the field of technologies, are listed. The main definitions and necessary clarifications are discussed.

Keywords: production technology, provision of services, matrix form, measured properties, experimental errors, classification systems, faceted classification, coefficient of uncertainty.

Introduction: Three Main Questions of Human Knowledge

Unlike animals, man does not simply react to the influence of the external world. Over the time the human behavior, i.e. a sequence of his actions, begun to be tied up with specific goals [1; 2]. Just the presence of a goal of actions differs humans from animals. Therefore, we can speak about the specific human property denoted as the mind. If a human has any goal in his or her activity this activity can be divided into a number of concepts. The first concept is to find and understand the externalities, which create a human activity in a given situation. The second concept must give an answer about a desired final result of activity. The third concept is to outline the principle of a path from the starting externalities to the final state of the system: human-environment. There are some additional concepts valid for understanding of the whole situation. Yet, these concepts are less significant. One can neglect them in the first approximation. In this case, a human activity is described by help of three basic concepts. They are as follows: the initial and final states of human-environment system and the draft of consecutive steps to implement a desired result.

To manage an individual activity a human must have some preliminary ideas about the meaning of each concept of his or her activity. To formulate these ideas one has to answer some principal questions. To understand the concepts about both states of human-environment system one must answer the question WHAT. It means what is the structure of a situation? What parts has any object? What principal values of construction does one want to built? And other similar questions. The answers to these questions give us all main behaviors for both situations. If one has imagination about behaviors of two situations he can build a path of transformation from the initial state to the final one. It means one has to find an answer to the question HOW. It is possible after the answers to the question WHAT are already known. If one has found answers to the question of the second order HOW he can try to ask the third question WHY. It is the most general and difficult question. Let us explain this statement with an example. An engineer wants to design a very sensitive thermistor. After some investigations the engineer finds the necessary materials for this device. This is the answer to the question WHAT. Now it is possible to create a metallurgical method for production of some portions of the necessary alloy. This is the answer to the question HOW. It is possible now to produce the necessary devices. Yet, each persistent researcher can ask him- or herself the most difficult question: why a certain set of materials can meet all the necessary requirements to be used in this device. It is the most difficult, yet, a very useful general question. If somebody has found an answer to it then it would be possible to create a useful program, which can select materials and processes for design of a wide range of measuring devices. Such results give an answer to the question WHY. So one can say there is a chain consisting of three related answers:

$$\text{WHAT} \leftrightarrow \text{HOW} \leftrightarrow \text{WHY}$$

Human knowledge usually has tried to find answers to these questions consequently. There are two ways to run through this sequence. The first one is from simple to complex (from left to right on the sketch above). This way is traditionally denoted as synthesis. The second one runs in the opposite direction. This way is denoted as analysis or reduction. Historically, the first way was closely connected with human practice. One can rather treat the second way as theoretical or philosophical. These both ways of learning Nature always influenced each other. Therefore, all three questions mentioned above were frequently discussed simultaneously. However, the emphasis in their study has changed over the time and places.

It is better to write the questions in the chain above, in their advanced form. In this case, their meaning becomes clearer. So, we can upgrade the question WHAT to: WHAT IS IT? It is evident, in the first place the answer to this question is given in engineering and physics. Similarly, we can upgrade question HOW into HOW TO DO IT? The answer to this advanced question can be found in the field of chemistry and various forms of processing subjects. The most difficult it is to understand the answers to the advanced form of the question WHY. We simply upgrade it into WHY IS IT SO? The answers to this question refer to the basic laws of Nature. It is well known that some appropriate axioms and postulates must refer to the successively established system of laws. It is impossible to improve these basic statements. One must believe only them. Moreover, different groups of people believe in various axioms. Therefore, the basic theoretical ideas come from different assumptions. We can use them only on the conventional basis. This basis is very particular in many cases. That is why two principle theoretical areas are known. One of them is the basis of Natural Philosophy. The other one is the basis of Theology. It means these both areas look for answers to the same questions. Yet, basic interpretations of our perception of Nature are different. There is no sense to dispute about contradictions in these basic principles because it is a problem of personal faith, rather than knowledge. There is no need to refer to these basic questions when one studies a specific situation. Yet, it is necessary to keep this problem constantly in mind and periodically return back to it after a number of interesting results are obtained.

Human knowledge develops unevenly over the time, and in different areas. The area of processing was significantly improved in the last century. These processes are usually denoted as transformation processes. As a result, there is a need to develop new instruction strategies devoted to effective teaching of these processes. The main goal of this article is a brief presentation of the main ideas of this strategy.

Concept and Terms: Development of New Idea

This paragraph explains the sense of conceptions connected with the term “technology”. It is well known that man’s knowledge is linked with various conceptions. We can regard these conceptions as certain abstractions. The process of abstractions enables one to make serious generalizations. This is possible if one uses simplifications of his or her perceptions. Despite the enormous complexity of the Universe, it is possible to present its perception by humans as a result of modelling. One defines modelling as a simplified description that takes into account some behaviours. A loss of a number of important behaviours in the description of Nature is the price for simplification of the studied problems. Therefore, to study a serious problem one needs to have a number of different models. Since the ancient times many philosophers have studied the process of formation of new concepts [3]. One of the best overviews of the current situation in this field can be found in [4]. All studies of a new concept formation in man’s mind are detailed in this monograph. It is well known to distinguish a concept from one another; one has to use some definitions. All knowledge of the process of a new concept formation in human’s mind is related first of all to the field of psychology. Yet, there is the second problem, which is related to psychology only partially. It is the process of development of a new concept for a long time [5].

Let us discuss this a bit more. The first stage of a new concept formation is the process of separation of some perceptions from the others. It depends on repetition of several typical actions and its intensity. After some time, some awareness is created in man's mind. Step by step, individuals try to include their awareness in a set of communications. A very fuzzy view on this awareness creates a result. There is a need to denote this new view with a word or term. The first denotation is very approximate. Its borders are fuzzy. If a new denoted concept is useful it attracts more attention. Attention to a concept calls for its more detailed investigation. Two opposite changes are a result of these investigations. The first one is a result of different specifications of perceptions behaviour. This leads to a set of constrains and finally studied clear criteria for selecting the perceptions, which are the base of conception. One can say the border of conception became more rigid. It also means the field of possible external affectations connected with a concept narrowed. Thanks to the clarification of behaviours connected with a concept one can find these behaviours in a new field and situations at any time. Thus, a set of changes is created simultaneously with the first one. These changes include some new actions into the external ones. Therefore, this effect generates expansion of the area linked with the studied concepts. These two directions of changes exist simultaneously. Yet, they are independent of each other.

Even small changes in understanding of a concept or analysis of its new behaviours require changes to basic determinations. These new determinations are not in good agreement with each other. So, the first term used at the beginning becomes self-contradictory. After some time, a package of different determinations is formed, which makes the used terms unified. After some time the society understands a strong necessity for a new study of a set of determinations and for having the system of terms in order. Different ways of solving this problem are known. The best one is to organize a special institution or periodical conference, which are given the right to adjudge. Unfortunately, this way is slow and difficult. It is used quite rarely. Nowadays, the study of production services, materials and machines push people to use one or two basic terms with many contradictory determinations. All instructional strategies are based on the use of simple conceptions, which can be recommended for the e-learning process without serious problems. Therefore, we need to discuss all packages of possible determinations of the term "technology" below.

Concept of Technology: History of Terms and their Clarification

At the time of primitive tribes human activity was focused on provision of food and making simple tools only. The goals of human actions were very simple and indistinct. That is why the sequence of necessary actions was rough. Yet, little by little, our ancestors understood that the main target of their activity was to convert an object into a desired form or state. Gradually, a number of primitive actions necessary to achieve a desired goal grew. That means the transformations became more and more complex. As a result, a human had to keep in mind a lot of special information which tied up his goal and actions he or she needed to repeat every time to get the desired results. This situation was one of the main bases of human evolution. By the end of the prehistoric time, humans already had some basic knowledge about the simplest transformation processes. They were able not only to make different meals but also they could make clothes and weapons. They had the ability to work with seven metals, build houses, temples and fortresses. It is hardly possible to enumerate all their abilities at that time. At the ancient age people learned several methods to render different services. Yet, they had no idea that a service is also a special product, which is a result of some transformation states of environment. A close connection between production of materials and tools and provision of services was realized only recently. Ancient philosophers laid the main foundations of the modern understanding of transformation processes. Yet, they were the base of modern understanding and nothing more. Despite some success associated with transformation acts, the basic definitions and key theoretical terms in the field of linguistics did not exist at that time. Ancient people were not developed enough for understanding the necessity to divide the process of transformations and its tangible results and tools. In modern understanding it is the difference between a couple of concepts: technology/technique. Progress in understanding this was hampered due to the fact of very simple transformations processes of that time since all of them were associated only with manual work. At that period the division of labor was known in embryonic state. Over these and subsequent years it was a very skillful artisan who was a key person in manufacturing. It was a work of such qualified masters that contributed to the creation of the terminology.

Philosophers began paying attention to technology of transformation processes at the end of Renaissance. Many neologisms were introduced in Latin at that time. Some of them came from Greek words. Philosophers of different countries took part in this process. However, the greatest contribution to the new terms was probably made in the countries of the German language. The most widely spread word at that time in German was Nütslische Künste [6]. It was well known is English as Useful Arts. The new term Technology was at first used by the famous German scientist and lecturer Johann Beckmann. He was born in the state of Hannover. After some years of his work in Russia he returned back to Germany via Scandinavian countries. For the rest of his life he taught in the Göttingen University. The books written by him at that time became classic. The best of them were repeatedly translated into many languages. The last of them were printed not very long ago [7; 8]. After this, the new term Technology became widespread. At the same time his basic ideas and definitions were spread everywhere. Beckmann was a follower of Carl Linneaeus. Therefore, he could not ignore classification of technologies known at that time. At first, it was printed in the third edition of [7].

For more than two centuries after Beckmann all areas of technological concepts were studied actively. Over that period the linguistic problems connected with the used set of terms, many general problems of philosophy and especially interactions between technology and economics and political evolution [9-11] were successfully investigated. It became clear long ago that "The bigger the area of conceptions is included in a term, the less specificity" an output gives. To avoid inaccuracies of each situation one must artificially narrow the studied field. Yet, the main used term usually does not change. For this purpose it is necessary to give special definitions for selection of a studied area. For this reason a big package of different determinations for the term "Technology" was created. As a result, we frequently have to deal with different misunderstandings. This can affect the results. According to the previous paragraph we can say it is time to revise the whole package of definitions and terms linked with them. This problem is especially important for instructional strategies.

The best way to divide terms used for description of human activities is to study the possible types of transformations. One knows three terms which denote the degree of certainty of transformation results. They are: receipt, recommendation and production. It should be immediately noted that the whole system of transformations is frequently denoted as Technology. To be more exact, according to Beckmann's set of terms it would be better to say General Technologies. Instead of production, one usually used the word technology, too. It was proposed to differ these two denotations by help of uppercase and lowercase letters. It means Technology is denoted as a pair General technology and technology is denoted as production technology or production. Unfortunately, this convenient way is rarely used. Therefore, we have chosen a set of denotations written above.

Now let us denote the receipt or transformation receipt as a set of recommended actions which cannot give an absolute guarantee to receive the desired results. For example, a lady wants to cook soup. She never did this before and she does not know which kind of vegetables, meat, pepper and other stuff she can put into a pan. Her neighbor told her it was necessary to put all this and water into a pan and to cook this for a long time. It is clear, that a good soup would be cooked in this way only by chance. In this situation, nobody can give the necessary guarantee to get a desired result. One can denote the set of actions given to the lady as a recipe. If this lady had any experience in cooking and could read a cookbook, with more determined and detailed advice she could certainly make a soup. May be it would be possible to eat this soup. Yet, its taste could be very different. One can say, the actions written in the cookbook are recommendations or transformation recommendations. If this lady got a set of exact advice divided into a sequence, the taste would probably be in a desired range. If every time this lady or someone else can use this set of advice and each time receive practically the same properties, one can say this is technology or production. As a result, this analysis builds a chain of concepts, which are closely connected with the logical chain of terms describing all possible transformations or General Technologies:

RECEIPT → RECOMMENDATION → PRODUCTION

This chain suggests the whole area of possible General Technologies or Transformations split into three types of transformation processes: receipt, recommendation and production. Thus, we have found three independent zones in the area of concepts. They are related to three types of processes mentioned above. They are separated by transition areas or border layers. Under general analysis these borders cannot be located exactly. Their position should be studied in every real situation.

Three zones of concepts in the chain of possible transformations are correlated with different sciences. The receipt zone is the zone where general laws of Nature and Society are studied. In these studies the transformation processes have a supporting role. So, for instance, the experts in economics are looking for the transformation processes, which are a basis of the global industrial changes. These key transformations are denoted as General purpose technologies [11]. Therefore, most parts of economic, demographic and political studies [12] are tied up with this concept zone. The zone of recommendations includes transformations, which realization significantly depends on individual characteristics of a person. Many political actions, advertising programs, training strategies, medical treatments refer to this zone as well as fine arts. Finally, the third zone of production transformation includes processing of different materials, goods, technical devices, their packaging and transportation. The last two are examples of services. Services are also applied to the zone of provision technologies. Nowadays, a service is regarded as a typical transformation of knowledge, skills and information into an object that can be sold:

THE FIRST MAIN DEFENITION: Provision of service is transformation of knowledge and skills into something that has a price.

THE FIRST CLARIFICATION: The zone of production transformations combines manufacturing of something tangible and provision of services. Creation of new knowledge in some situations can be included in this zone, too.

All students on tertiary level must be familiar with this introductory information. It may also be useful to find alternative terminology as: Arteology or Science of productions and professions [13], Evriology [14], Ppaxiology [15] among the few. Senior students have to learn all subjects in detail from conceptual zone connected with their future occupation. The main interest of this presentation is to discuss instructional strategies for future engineers. Consequently, we should pay our attention to the subjects from the zone of production transformations.

Non-Formal Study of Transformation Triad

The theoretical system should start with the generalization of empirical information. The first results of such theory cannot use serious mathematical descriptions. Therefore, and it is very important, there is a gap of non-formal empirical study between the collection of the facts and building a formal mathematically based model. The best way in this case is to save quasi-mathematic form of presentation. Yet, all conclusions in this form have only empirical evidence. All rigorous proofs are avoided. According to Johann Beckmann's lectures, all transformations which one calls technology were processing or fabrication of Objects a human needed. Natural materials or any Objects were a source of conversion. So, the central production technological process was determined as a triad:

INPUT OBJECT → PRODUCTION TECHNOLOGY → OUTPUT OBJECT

Some other interactions in the system are regarded as secondary. Since the output object is something a human needs, its behavior must not be accidental. To guarantee this desirable quality the fabrication process has to be strictly specified. Thus, modern and convenient determination of production transformation is as follows:

THE SECOND MAIN DEFENITION: Production transformation or the same production technology is a strictly determined sequence of operations that guaranties a desirable result.

THE SECOND CLARIFICATION: The desirable result we denote as the output object may be material, machine, knowledge or service somebody needs.

THE THIRD CLARIFICATION: The base of production technology is an algorithm or the sequence of operations that can predict a final result. Production technology produces or transforms some initial things or goods into desirable objects which can have different nature.

The middle part of the triad described above is defined as the METHOD or MANUFACTURING PROCESS. Numerous observations confirm that it is a common situation when people prefer to study only a method. There are plenty of situations when neglecting of input object behaviours is justified. One can find some examples of this simplified analysis in instructional strategies, political actions, medicine. As it will be shown, such simplification sometimes produces undesirable mistakes. The second important moment of production technology is its close relationship with several known theories, e.g. Theory of engineer design, Theory of inventions, Theory of creativity are among them [16]. A bibliography of this issue can be found in [17]. It is important to note that many of authors in [16; 18] came to the triad form of transformation processes. Moreover, some authors finally began using several definitions, which, by it sense and form, are close to ours.

So, E.W. Eder [18] gave such definition: 'An operand (materials, energy, information, and/or living things – *M*, *E*, *I*, *L*) in state *Od*1 is transformed into state *Od*2, using the active and reactive effects (in the form of material, energy and/or information – *M*, *E*, *I*) exerted continuously, intermittently or instantaneously by the operators (human systems, technical systems, active and reactive environment, information systems, and management systems, as outputs from their internal processes), by applying a suitable technology *Tg* (which mediates the exchange of M, E, I between effects and operand),whereby assisting inputs are needed, and secondary inputs and outputs can occur for the operand and for the operators.'

It is not difficult to notice that practically all terms in this definition have unambiguous and clear equivalents with the definition given above. For instance Operand is a mathematical term that denotes the same concept as word Object in our case. Over the last decades many useful materials devoted to study of different business processes have been written. They were focussed first of all on management. All these materials considered management as transformation, which has the same triad form as mentioned above [18].

Let our reader take into account that [13; 16; 18] are typical training materials. It means the problem analysed in this presentation draws wide attention, indeed. Therefore, these materials describe transformation processes from the general point of view. For the general study of complex systems one can use two ways. The first one is the consecutive division of the overall relationships on smaller parts, i. e. the way from the top to the bottom. The second way runs in the opposite direction: bottom-up. It is based on the generalization of different particular situations in different technological zones. The ratio between these two ways changes forms of different technological zones. Processing of materials, goods and machines traditionally prefers case studies. This zone of production technologies includes many practical processes. Their description was usually independent for each situation. Therefore, one of the most important tasks now is to combine the results in a single convenient system. It can be realised based on the general empirical theory. It will be discussed in the next paragraph.

General Empirical Study of Production Technologies: Assumptions and Conditions. Foundations of Introductory Courses at Tertiary Level.

General achievements in human life in the last century turned the progressive interest to the theory and practice of production processes. This, in its turn caused a rapid reconstruction of instructional strategies. Active introduction of computers in all fields of modern life changed the approach to all human activities. Everyday practice uses processes called Computer aided design – CAD, Computer aided teaching – CAT and many others. A careful observer will notice the similarity with classical definitions of Production Technologies (see above) and all types of computer control. Therefore, the Computer aided production technologies and Computer aided processing technologies become a field of high practical interest. One abbreviates both of these processes as CATT. Consequently, it is necessary to introduce all modern achievements in this field into the curriculums. It is clear for all curriculums CATT has to be divided into two parts. The first one is an introductory course that makes the students aware of the general laws of CATT. The second part is connected with the future specialisation of students. It is taught at the pre-diploma period. The introductory part is based on empirical regularities. The content of the second part must introduce the empirical laws into the formal mathematical description. This paragraph is devoted to empirical laws of introductory lectures.

In the Western countries the path dependence in researching strategies was focussed on provision of services and natural philosophy [24]. The East European countries focused maximum attention on manufacturing processes. There were several periods during which the exchange of scientific results between these two cultural communities was weak. As a result, the generalization of studies in the field of manufacturing technologies was mainly developed in the East European countries. At the same time, the general theories were mainly developed in the Western cultural region. They were devoted to provision of different services. The first steps in the generalization of case studies in manufacturing technologies were taken in the former USSR and Czechoslovakia. After the Czech authors moved to Canada the investigations in the general theory of production technologies continued mostly in Russia [20-22]. The issue [20] was the first attempt to build connection of general empirical studies and specified processing in the field of materials of high purity. The book [21] is a complete empirical theory of production technologies in their modern state. The article [22] is a brief narrate about the results of [22] in the English language. These results are preliminary materials for a new instructional strategy. The general empirical laws of this theory consist of several assumptions and conditions. The main of them, which are necessary as the basis of teaching in different universities, are written below.

THE FIRST BASIC ASSUMPTION: It is possible to study production technologies without any impact on the whole cultural system of the society.

At the first glance this assumption seems a little strange. Yet, it is necessary to take into account a lot of issues related to mutual impact between the cultural environment and technologies. This assumption supposes that there is a real possibility to build a reasonable model which enables to study the field of production technologies independently from their connection with the evolution of the human society.

THE SECOND BASIC ASSUMPTION: The Object of interest constantly changes its input properties at the time of processing. Despite this, there is a real opportunity to maintain the input properties of the Object stable at the period of its technological transformation. This may be realised if the velocity of the Objet changes slower in comparison with the velocity of transformation processes.

This assumption says one can repeat production transformation for many times. For simple engineering thinking this is the statement about reproducibility of the transformation process.

It is very well known there is no complete identity of different (not the same) Objects in the world. Yet, one can introduce:

THE THIRD BASIC ASSUMPTION*:* Despite a lack of complete Objects' identity there are a number of situations where one can receive reproducible results in the situations of practical human interest.

These two assumptions say in the hidden form about the existence of a valid range of objects' properties and modes to support the reproducible transformations.

THE FOURTH BASIC ASSUMPTION: The results of all transformations are independent on each other. It means all synergetic effects may be neglected.

This assumption provides for linear mathematical approximations. It is the weakest assumption from this set and there are well known different practical situations where it is broken.

These assumptions are not usually specified as concerned to be natural. In practice their non-compliance occurs rarely. Yet, a qualified expert must understand the necessity to check them in each new situation. That is why this group of assumptions should be included into an introductory lecture course. In these introductory lectures it is useful to take into account that all technologies constantly change with time. Evolution of changes in technologies is slow. In each technology there are changes in which the properties of technology change at the processing time with a high speed. These changes repeat periodically. One denotes these changes as dynamics.

THE MAIN CONDITION: To get effective results in the study of different kinds of technological transformations the speed of dynamical changes should be much less than the speed of evolution.

The implementation of this simple condition allows us to investigate many kinds of technological transformations without taking into account evolution changes. They, in turn, can be investigated independently. Therefore, the evolution changes of transformation processes can be studied independently. As a result, the laws of technological evolution can be formulated in a very universal form.

ADDITIONAL CONDITION: It is desirable to design new production technologies after development of the criteria of their effectiveness, which may vary for different situations.

Only after students learn these main provisions of introductory course it will be possible to start teaching the subject-oriented tasks to them. There are three thematic clusters that form the basis of curriculum. They are as follows: 1. Classification systems of transformation technologies; 2. Convenient and universal system to reflect behaviours of all three concepts of transformation triad; 3. Methods of estimation of all possible errors in behaviours of Objects and characteristics of transformation modes.

Principles of General Classification of Object Transformation

The importance of creation of a classification system (taxonomy) for the whole package of technologies is known from Johann Beckmann [7; 8]. Since then, many different systems came up. However, a single convenient system still does not exist. The Bologna Process forced to address this issue in order to unify curriculum. People have enough experience to use different classification systems. Several principles may be identified in the classification systems. The most well known are hierarchical and numerical systems. Each of them is divided into some groups. The whole field of technologies includes many different objects and transformations. Each of them can be described with their own taxonomy. The facetical classification is known as the best among such complex systems. Facetical methods belong to the numerical systems. It enables to put objects in order in multiple appropriate ways. The number of facets and their order may be changed without any problems, enabling the classification to be ordered in multiple ways, rather than in a single, predetermined, taxonomic order. All objects' behaviours of an individual facet may be studied independently. That is why the facetical classifications are the best method of studying the whole technological field. In the first place, they are convenient for the general studies of philosophical sense of technologies. This task is the most interesting for the introductory course. Specific technologies have practical interest for control, design and cataloguing of different operations and actions. There is no sense to use and teach them to know general philosophical concepts. Therefore, it is convenient to divide the whole classification of technologies into two practical independent parts. The first one: Genefrative Classification describes the most common properties of technologies. The second part: Specific Classification is devoted to specific transformation technologies. In this part the best way is to tie up the facetical principles with the hierarchical ones [20].

There are different ways to choose a starting (upper) facet of Generative Classification. One of the best ways is to start with a facet, which reflects the interaction between a human and a transformation process. In each case a person manages a transformation process of objects. If a human transforms a non-living nature he or she is a managing entity in the technological process. This human observes and studies the process from the outside. We shall define these types of technologies as Industrial ones. The directed transformation of different objects is not restricted by industrial processes only. Teaching represents a directed transformation of students' KSAs. Advertising is also a process that changes customers' information about different goods in a predicted way. In this case, a human is both a subject and an object at the same time. One can say the whole sphere of technologies can be divided into three different parts or zones. The third zone is the zone in which a human operates the process and at the same time he or she is the Object of the transformation process. The technologies included in this zone are defined as Humanitarian ones. So, the division of these three parts is associated with the relationship between humans and technology. If humans are not involved into the technology and can only observe it, or can manage it, we have industrial technologies. If the technology actions affect humans, this is the case of humanitarian technologies. Advertising and company management are a few among them. If a human being is an action party and an object of technology action at the same time, we can say this technological process is Combined. Psychological, medical, and learning technologies are excellent examples of the combined technologies. Investigation of the real border between these types of technologies and study of their principal differences is a problem of great interest. Thus, the educational and instructional technologies are a part of the combined zone. It is interesting to notice the authors which are focused on the general and philosophical tasks of technologies also noted the importance of human position in the pair: human/interaction. Andrew Feenberg, the author of [23], wrote an overview with the same title [26] in which he wrote:

Technology is a two-sided phenomenon: on the one hand there is the operator, on the other there is the object. Where both, the operator and object are human beings, technical action is an exercise of power.

It is essentially the part of the same idea. Yet, the philosophy and economics are interested in technological transformations in which a human is inside the process. Contrary to this, the production technologies are interested in the investigation process, in which a human is fully or partially outside the transformation actions. As a result, a human can predict the results better and has a better possibility to control the sequence of impact actions.

MAIN PROPOSITION: The position of a human or operator in relation to a number of active actions is the base for division of the whole field of technological transformations or The Field of General Technologies into the three principal zones: zone of receipts, zone of recommendations and zone of processing.

It is necessary to say:

FIRST ADDITION: The borders between the three main zones of General Technologies are not strictly denoted. They are vague interface areas.

Consideration of a new set of facets is real after the study of production technologies is separated from the study of technologies as a part of society behaviors and evolution. One of these facets divided the production technologies into open ones and confined ones. The second one is related to the origin of actions in the technological sequence [21].

PROPOSITION: There are four groups of production technologies determined by their origin. The first one consists of actions created by humans. They are denoted as industrial technological transformations. The second group is based on actions that are created as a result of animal evolution. People purposefully use only them. One denotes them as naturally created production technologies. The next group uses both, the production technologies created by humans and the technologies independently created in the nature. One denotes them as a combined group of production technologies. At last, the fourth very complex group is the production/provision of service. The enumeration of these groups is comprehensive because each new transformation process will be assigned to one of these groups.

These two facets may be included both into an introductory course and a specific part of curriculum. This depends on a future specialty of students. In the instructional strategy of engineers these two facets are the task of the first lectures. Further teaching of the theory and practice of industrial technologies is combined with the traditional taxonomy, which form is traditional and it is adapted to the conventional computer system. Some examples of such system are described in detail in [21]. It is very convenient to use the so-called Koller indexes [25] in specific taxonomies.

Components of Technological Triad. Foundation of their Formal Description

There are at least three basic concepts of technological transformation. The formal description of transformation must reflect the way of changing a set of properties of the input object into the set of the output one. They can be both quantitative and qualitative. Yet,

THE FIFTH ASSUMPTION: Each property can be numerically expressed, if necessary. One of the four types of measurement scales (nominal, ordinal, interval or ratio) must be used for this purpose. The standard methods of their measurement will be the way of receiving the necessary values. The values attributed to properties can be normalized to standard interval [0-1].

The formal study of production technologies needs to use simple, exact and convenient description. According to the concepts of [16; 20] one of the best ways to solve this problem is the transition to matrix formalism. Let one denote the input Object as A, and the output one as B. The full sets of their properties will be $\{A^j\}$ and $\{B^k\}$. Their numerical values consequently are $\{a^j\}$ and $\{b^k\}$. The simple transformation must transfer several values from $\{A\}$ to their desirable values in $\{B\}$. It may be written by help of transformation matrix $\{T\}$. The matrixes $\{A\}$ and $\{B\}$ are one-column matrixes. The processing matrix $\{T\}$ is more complex. It reflects indexes of different input and output properties. It is a rectangular table. Each value in it has two indexes. One of them relates to input and the other one to the output values of any property. If we write the numerical values in the form ||C|| the technological transformation will be written as:

$$T||a^i_m|| = ||b^i_n||$$

This formal expression is compact and convenient. Therefore, it is used in several general studies of processing and technical design. If somebody wants to make a catalogue of processing actions he or she would need to study all details of $\{T\}$. They depend on matrixes which saved the properties of $\{A\}$ and $\{B\}$.This general analysis is enough for abstract theoretical studies. If one needs to get some specific results he should study the structure of object properties matrix in detail. The main results of such study were collected in [20].

FIRST DEFENITION OF PROPERTIES: Not all properties of the object are interesting for practice. The properties responsible for behaviours are transformed into the price. One denotes them as the customer's properties. For different use of the same object a set of customer's properties may be different. Other properties are denoted as neutral.

TE FOURTH CLARIFICATION: A set of properties has hierarchical structure. The customer's properties are the properties of the top level of the hierarchy. They depend on the properties related to the lower levels.

For example, the quality of thermocouple depends on some physical properties: resistivity and thermal conductivity first of all. These two properties depend on the concentration of current carriers. The later property may be treated as more fundamental. So, to build a correct and effective transformation it is necessary to affect on the most fundamental set of known properties. The serious problem is connected with fact that different customer's properties can be tied up with the same fundamental properties. In some cases, when one improves one property, another property is improved at the same time. It is the case of Directly connected properties. The opposite situation is well known as well when improvement of one property worsens another one. It is the case of Opposite Directed properties.

THE FIFTH CLARIFICATION: To build effective formal theory of production technologies it is necessary to study the properties of all objects that may be relevant to the transformation actions. The foundation of this knowledge is connected with the principal laws of natural sciences.

All these tasks determine the main content of specific subjects learned at the pre-diploma period. At this time an instructor must attract the students' attention to another issue. We wrote above that there are many situations where the input objects are regarded as stable. As a result, the operators frequently stop controlling the properties of an input object. So, instructional strategies forget about the psychology-content behaviour of students. In other situations a form, which manipulates with materials, reduces the input control. In these and in other similar cases even weak changes of input properties or fluctuations in the processing conditions can suddenly create unexpected results. The same situation is well known in provision of services. Therefore, the sociological control is a necessary component for all social and political sequences of actions. In the lecture course it is useful to give one- or two historical examples, which can illustrate this situation. It is possible, for example, to say that German politics before 1939 was based on sustainable view regarding the position of European politics reaction on their acts of invasion and big war. Nobody tried to study the state of mind of the citizens in each country subjected to the aggression. This is the reason why the reaction of Poland was so unexpected. It was a typical mistake connected with a lack of data about the initial situation. The similar mistake explains the beginning of the France-Spain war at the Napoleon I period, too. An experienced instructor has to have a package of interesting examples to illustrate the necessity of constant input control in all production technologies.

How the Errors in Values of Properties Affect the Results of Technological Transformation: Target Setting

To be effective, a goal of each transformation must be measurable. An operator needs to get numerical information about all components of technological information. Numerical analysis improves the understanding of all transformation processes. Each numerical value is measured with an error. For the value a^j its error is denoted as Δa^j. All numerical values in triad matrix are known with inaccuracy. Inaccuracy characterises transformation actions, too. Therefore, it is possible to realise the numerical characteristic of The output object with some inaccuracy, too. Nobody can get an Object without inaccuracy. If a wanted inaccuracy is higher or equal than inaccuracy received after the end of transformation one can say the principal goal is achieved. It is an excellent example of ideal production technology. If a final inaccuracy is more than desired one can speak about some deviations in the processing goal. The value of this deviation determines the value of the so-called uncertainty. This property is measured by help of the coefficient of uncertainty [26]. In this work it was shown that for this coefficient it is very productive to separate the production technologies from recommendations and receipts. The critical values of this coefficient are an indicator which enables to find a border between these zones. Location of the border depends on the chosen critical value of the identifier. It means the position of this border is movable.

THE SIXTH CLARIFICATION: The provision of services frequently does not permit to give numerical values of the output situation. Accurate terminology uses the term “goals” for a process which results are measurable. The term “target” is used when the processing results are rather qualitative. Both, goals and targets should be achieved after some transformation actions.

When thinking about goals it is important to quantify them so that the progress can be measured and assessed. But we need to be realistic about the goals we are able to achieve. The goals should be based on knowledge and rationality. The targets are frequently based on emotions**.**

All what is written in this paragraph is quite simple. The theory of errors is taught in most universities. Despite this, the formal theory devoted to impact of errors on production technologies is missing. At the same time it is clear that this problem should be investigated in detail and urgently. In our opinion, the best way in this situation is to involve the students in this interesting and useful field. The simplest way, which we recommend, is to discuss this task at the period of pre-diploma work. Different students’ research works in this field are also desirable.

Conclusions

The general study of production transformations of different objects is a very important field for the formation of modern background of a graduated expert. The most reasonable way to teach different issues connected with this field is dividing all tasks into two different parts. The first introductory part has to be learned at the sophomore period. It is the part in which the general laws are taught. The second specific part must be taught at the pre-diploma period. This part has to be specified for different engineering specialisations. This article mentions many problems necessary to study in modern instructional strategies. They are very important. The best way to introduce them into curriculum is to conduct preliminary general discussion. It must be realised on the base of international cooperation of teachers, instructors and researching staff of the leading universities.

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