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About utilizing the concept of the Engineering of Needs (EoN) in the Technology Assessment(TA) approach

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Summary:*The article introduces some extensions of the author's earlier thoughts, as presented in his previous publications, regarding the investigations of needs in contemporary engineering activities. In the first part a concept defined as "Engineering of Needs" is briefly shown. Then some proposals to extend this concept, especially in terms of methodology and tool, are presented. The second part of the article is dedicated to reflection on the role of Engineering of Needs in activities related to assessing of products, services and technologies in accordance with the approach of "Technology Assessment".*
Key words: *needs in engineering activities, technical aspects of recognition and analyze of needs, Engineering of Needs, Technology Assessment*

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I. Introduction

The contemporary world, especially thanks to the achievements of science and technology, is indeed a world of technical revolution. However, the above statement does not mean that the author of this paper is referring to the fashionable concept of "Industry 4.0". Observing the current changes in the amount of our knowledge and skills, wich result in overcoming the subsequent barriers of difficulty (or even inability) to solve by humans problems of technical nature, we have the right to conclude that we can do almost anything. That is why - in the opinion of the author of this article- it is time to rethink also the role of technology in society in variety of possible aspects of this role.

It seems to be worthwhile to investigate consequences of avalanche growth of our technical capabilities. Of course, such consequences are potentially very diverse and cover or potentially cover an extremely wide range of problems. This undoubtedly requires, especially from the scientific community, to undertake the debate and research of all of this, as evidenced by the increasing level of omnipotence of modern man in executing the Creator's recommendation: " Be fruitful and multiply and fill the earth and subdue it, and have dominion over the fish of the sea and over the birds of the heavens and over every living thing that moves on the earth" (Genesis 1:28).

Even if we came down from heaven to earth, it has to be stated that the debate on above mentioned issues has been going on intensely since many years, as evidenced for instance by ideas for reflecting on the meaning of science to society (concepts “SaS - Science and Society” and “SiS - Science in Society”). These (and related) concepts were presented with an extremely rich collection of publications, which even a very brief summary could evidently not fit in a single article.

Therefore, the author of this paper decided not attempt to comprehensively refer to the results of research on the role of creating technical solutions in the development of people and societies. This article refers to the relatively narrow aspect of the technology creation process, which can be perceived in relation to the "classic" question sequence: What? Who? Why? and How?

In particular, the following chapters of this article is an attempt to link the question of the desirability of carrying out a technical task with the reasons for undertaking such a task. The meaning of such a formulation of the problem arises directly from quite obvious question:

- Can the fact that we can (do) something to do is a sufficient reason (premise) to make decision onto act in order to realize the existing possibility?

Due to his "engineering biography", the author of this article attempts to refer the above question to the activity of the engineer - the creator of technology. In many publications, both formerly (e.g. [1]) and now (e.g. [2]) the authors have attempted to systematize a glimpse at all the activities aimed at creating and sharing artifacts, modelling them as a sequence of design, construction, manufacturing and exploitation activities. Usually, in this sequence the initiating point is connected with needs.Therefore, in this article the answering of next question is treated as a key problem:

- What is a role of needs in engineering?

It is worth mentioning here that the consideration of needs is not related solely (and may be even not primarily) to the technical view. For example, in the paper [3], the authors present a long list of sources that address various aspects of knowledge about needs in various fields of science.

In this paper, as a preparation for further considerations, the author carries out a selective review of problems related to the "technical" needs survey.Coming out from this review as well as from the reflections presented in previous publications ([4], [5]) and focused on a general outline of the concept called "Engineering of Needs," the author formulates some further comments aimed at developing and refining this concept.

Lastly, given the potential scope and complexity of considerations even limited to the "technical" need concept, the author of the paper further limits once more the scope of his reflections by undertaking an attempt to link "engineering look at needs" with processes of evaluating products, technologies and services in terms of "Technology Assessment" (TA).

II. Selectivereview of problems of identifying and investigating needs

The presented below review of problems is biased in two ways: by the engineering point of view belonging to the author if this article and by the limited volume of this study. Therefore the contents of this chapter is assumed to present briefly some recent thoughts of the author and be a starting point for presenting some new aspects of considering problems of needs, both in research and application sense.

Even by limiting ourselves to the need in terms of engineering, i.e. a class of needs which are "triggering" the process of satisfying it by designing, constructing, manufacturing, and giving to the user / user of a particular product (technical means), we will not avoid the question about an origin of the need. The author of this paper asked on the ResearchGate forum [6] the question formulated as follows:

Is the origin of human needs, considered by scientists representing different research fields, objective or subjective?

with the following comment:

"In the discussion of my previous question on the ethical dimension of needs, there appeared, among others, the problem of source/origin of needs. In particular, some of colleagues responding to my question formulate a thesis that needs exist or appear as if objectively, i.e.. regardless of someone's intentions or actions. In turn, I believe that in many cases the needs are created ("designed")".

The answers were different and strongly connected with the "scientific origin" of scientists taking part in the discussion. Anyway, these answers have had some common element: it was pointed that the nature of needs may have a significant impact on further steps in processing: recognizing, describing and using results for next steps of processes of meeting the needs.

The above question, undoubtedly of very general dimension, evidently leads to the next question, which forms a description of the problems that need to be addressed in the area of identification (identification) and research (analysis) of needs. The list of such problems may include, for example, the question of the practical dimension of objective or subjective character of needs.

With many examples illustrating the potentially subjective nature of the needs associated with contemporary technology development, we see that needs can be stimulated or even created, using often sophisticated tools and involving significant financial resources.

Probably a fairly obvious example here is the history of mobile phone development. It shows - on the one hand - the situation in which the development of a technical means has led to the creation of a collection of its functionalities, where the basic - seemingly - function of the phone, which is the distance call, becomes one of many, perhaps not even the most important function realized via a device that we still name the phone. On the other hand, it is worth asking: are these additional functionalities of the modern mobile phone a results of the recognizing needs? What would the average user of such a phone say twenty years ago asked what he expected from the news offered in the time horizon on the market for such devices?

If we try to consider the needs resulting the broadly understood development of technology as a result of forecasting processes (perhaps it is worth considering the use of foresight-like tools in the discussed area of problems) the result of this still is a subject of subjectivism. With quite a lot of freedom in accepting assumptions and evaluation criteria in such processes, the use in processes related to identification and testing needs, for example, of forecasting tools, can result, in the effects of functioning the self-checking forecasting mechanism, under certain conditions. To sum up, it seems quite obvious that a lack of objectivity in formulating, analyzing and evaluating needs is a common phenomenon.

Further, next general questions about needs may formulated like:

- Does a need has (or should have) the nature of the requirement or an expectation?
- Are the "technical" needs appearing (occurring) or are created?
- Has the process of formulating needs (or should have) the nature of "bottom-up" or "top-down"?
- Can the need be treated as justified or unjustified?

An additional, but certainly not the least important, set of problems related to needs, are also ethical problems. Pretty easy to find, according to the author of this study, arguments for asserting that need-oriented analysis can be (often is) the subject of manipulation. Would it be an interesting research issue for professionals to define rules for a specific "Ethics of Needs"?The question about this problem asked on RG forum [7] has caused very interesting discussion.

When we come back to the „technical thinking" about needs, it is suggested to base this thinking in the following set of problem questions:

1. What is the source of the need?
2. In what categories (qualitative, quantitative, mixed) are we able to recognize and describe the need?
3. What does the recognized need concern?
4. Is it possible to meet the recognized need?
5. How can be the recognized need met?
6. Who can meet the recognized need?
7. What are the positive and negative effects of meeting the recognized need?
8. What are the positive and negative effects of lack of meeting the recognized need?

Technical thinking about needs offers a selection of tools that may be useful for assessing needs in a practical setting. A good example of this type of tool is the use of hierarchical models, commonly used in classical methods of constructing, manufacturing and using machines and devices (machine - assembly - sub - assembly) [8]. The methods and tools applied in dealing with data sets (hierarchical databases [9], control structures [10]), can also be used in the needs survey.

In particular, models based on a hierarchical structure may enable analysis of "needs in need" (Fig.1). Translating the above statement into the language of technology, the machine, the device, but also the IT system can be seen as a hierarchy of elements arranged in mutual primacy and subordination. It may allow to indicate which elements of the hierarchy of needs are more or less conditioned by satisfying the initially identified (basic) needs. Addition of this approach to appropriate quantitative tools (indicators) may be the basis for decision on ranking the needs to subordinate their impact on meeting the superior need ("vertical" dimension) or ranking the same level of needs, eg to determine the order of meeting such needs ("horizontal" dimension).

The approach shown in Fig. 1 can be particularly useful in situations where meeting the "overriding" need X requires meeting the "subordinate" need Y. Alternatively, the result of the analysis may be that the overriding need cannot be satisfied in the present state of the art, i.e. faced with difficulties or lack of ability to satisfy one or more subordinate needs. The problem described well, according to the author of this study, illustrates an example of the need to place on market electrically driven cars. Satisfying this overriding requirement is strongly conditioned, among others, by the effective meeting the need for the energy source used by such a car.

Continuing the above considerations on the simultaneous study of multiple needs, it is useful to identify effective quantifiable tools for determining the validity of the needs in question. It seems that it would be possible, for example, to assign to elements of a set of identified needs ranks, i.e. the use of selected tools of classical rank analysis ([11]). Of course, it is important to point here to the importance of choosing the criteria according to which the chosen need / needs are given a higher or lower rank. Basing on such evaluation, we treat them as more important or - respectively - less important than others. As in processes of optimization, the choice of criteria has a significant impact on the ranking of needs.

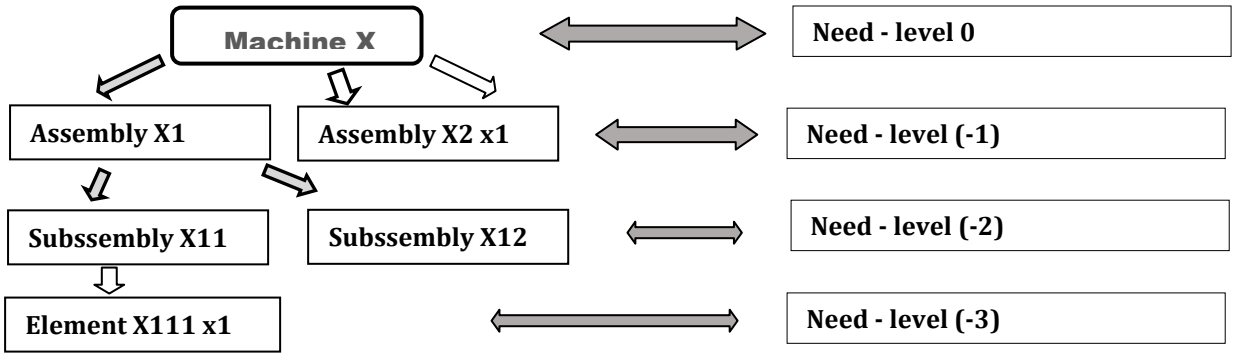

Fig. 1. Identification of needs related to the hierarchical structure of machinery / technical means

The meaning of the approach, shown schematically in Fig. lead to conclude that in many specific cases, the development of technical solutions initiated by Level 0 needs (i.e. the needs resulting in the creation of a

new machine/device) is conditioned by meeting the needs of a lower level (i.e. the needs for a component of such a machine: its assembly, subassembly and/or element). This problem can be illustrated - once again - by example of the implementation to universal use of electric cars. Satisfying the need at level 0 is in this case essentially conditioned by meeting the need for a lower level: the need to create a suitable "storage device" of electricity (batteries). The example of an electric car also shows a significant problem in taking into account the need for levels higher than level 0. In particular, the element of meeting the need is to identify, assess and meet the needs for the effective technical infrastructure in which the electric car will operate. The key element of such infrastructure are undoubtedly a suitable net of the car battery charging stations.

Probably one could continue to ask questions related to research of needs. The problem set out above can be extended considerably in the many, and yet to the least, aspects. Therefore the author of this paper has decided to treat the question of needs, identification and research as an open problem, and to try to answer some of the questions already formulated, especially questions embedded in broadly understood technology. As a basis for such responses, the general concept of "Engineering of Needs" was adopted.

III. Selected elements of the concept of "Engineering of Needs"

The idea of treating activities related to the identification and analysis of needs, and aimed at making appropriate decisions and resulting in further actions in the process of creating machines and devices (more broadly: technical means), as technical activities, the author of this work presented in general in his earlier publications ([4], [5]). In the approach developed by J. Dietrych [1], a cyclic model of the designing, manufacturing and use of machinery/equipment was proposed and named as a "model of the process of meeting needs".

This model (shown schematically in Figure 2) assumes in particular that the phase of recognition, identification and description of needs (rp) in the process of meeting needs is "fed" by data, information and knowledge derived from previous process cycles of the process. In other words, if the identified in a previous cycle need caused designing, then manufacturing and exploiting of a technical device (machine, device, installation, also an IT tool), observations of that technical means during operation (ep) can be the basis for changing the view of a need, supplementing or modifying its description, which in turn can be the basis for "launching" the next cycle of the process.

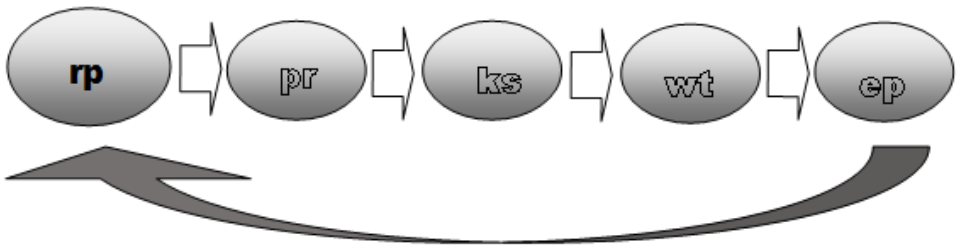

Fig. 2. Model of the process of meeting needs according to J. Dietrych [1]

Such a view of the process of meeting needs should be undoubtedly complemented/extended. First and foremost, it is difficult to limit the impact of data/information/knowledge from the previous cycle, influencing new vision of needs, solely for the observation of phase-related activities. It is possible to justify the existence of an impact on the new vision of the need also for experiments, especially related to the processes of manufacturing a particular technical unit (**wt**), as well as, in its work. The creator of the primary model formulated a problem called a"rationale existence" for the product. Demand of the rationality is distinguished for productive technology. According to this approach, technological factors are considered to be influential in the design, construction and production of technical means. As the key factor is also understood the availability of the technology which enables the creation of this technical means. It is also worth examining also the impact on the new vision of the need for at least experience in the phase of creating design documentation (phase of designing: **ks**). The existence of such additional links in the discussed model (they can be defined in functional sense as passive feedback) is shown in Figure 2a.

So that, the thesis can be formulated that states the need, as a starting point of the chain of engineering activities, is itself a complex of various components. A graphical illustration of this thesis is shown in Fig. 3, indicating at the same time the requirement to maintain the fixed sequence of actions: first we collect data/information/knowledge from available sources, then describe the need and evaluate it in the light of the selected criteria.It is worth noting that the sources of data/information/knowledge shown in Figure 3, which make up an image of need in a particular case, not must always occur together.

And so, we can consider the case of a "new" need, generated only by the collection of past experience gained in the process of satisfying the similar (earlier) needs. Another possibility is to include in the description of the new need not only the above mentioned past experiences but also the results of research available e.g. in

the form of patents or "know-how". Finally, the new need can - as in Fig. 3 - combine data/information/knowledge from all three of the above source types.

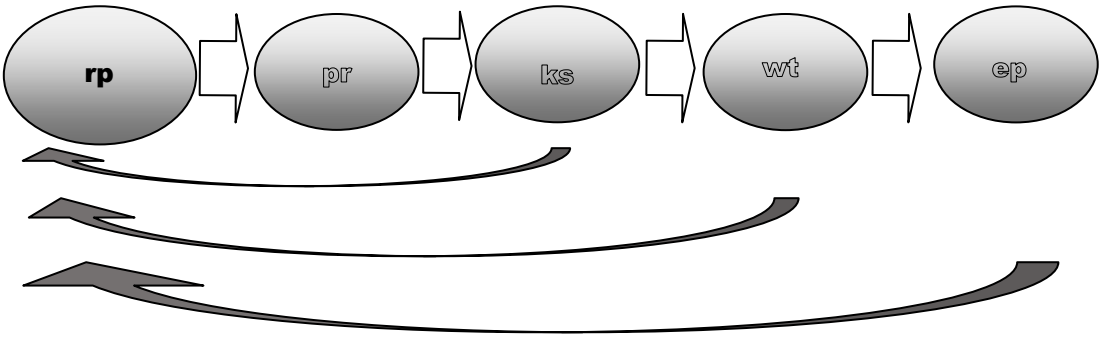

Fig. 2a. Model of the process of meeting needs, taking into account additional links (feedbacks) influencing the recognition of the need

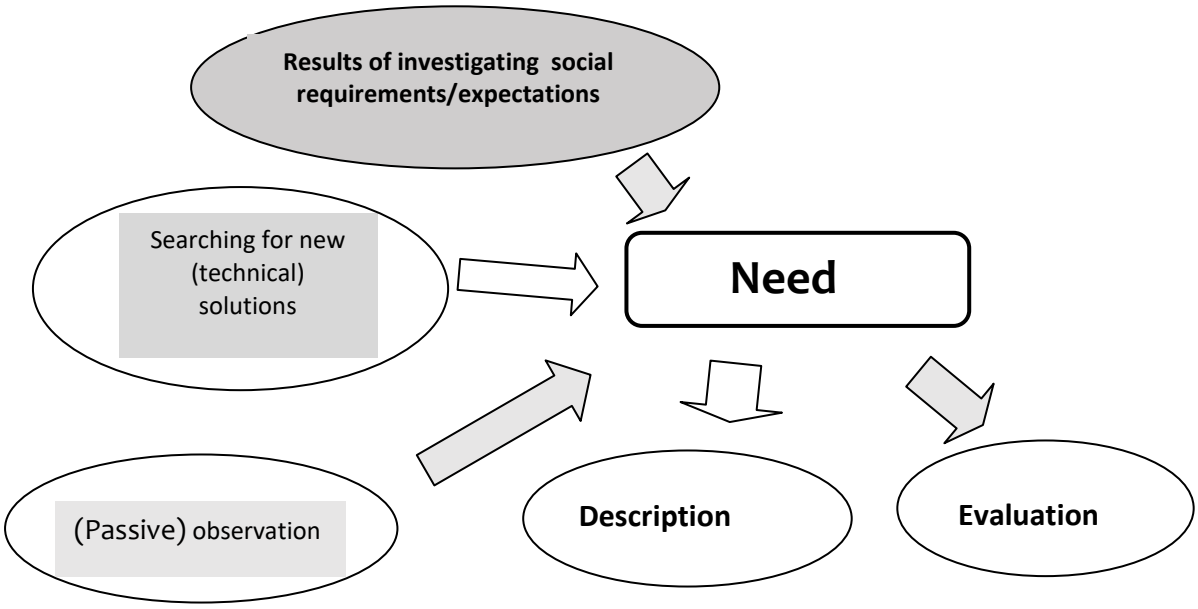

Fig.3. Seeing the need as a result of putting together data / information / knowledge from different sources (after [5])

However, the author of this paper believes that other combinations of the data, information and/or knowledge sources discussed herein may be also considered as potential variants of sources for identifying, describing and evaluating needs. Table 1 shows a summary of the basic, possible combinations of the above. sources.

Table 1. Variants of factors that generate needs in the area of technology

Number of variant	Previous experience (from exploitation of machinery/equipment)	Development of technology	Non-technical factors
1	+	-	-
2	+	+	-
3	+	+	+
4	-	+	-
5	-	+	+
6 (?)	-	-	+

In the earlier part of this paper, illustrating this issue in Figures 2, 2a and 3 in particular, the meanings of variants 1, 2 and 3 as shown in Table 1 were explained. Potentially, however, especially from a research perspective oriented not only to the engineering need, it would be interesting to consider the alternatives indicated in this table, i.e. variants 4, 5 and 6. It is well known that in the history of technological development, such "non-technical factors" as - for instance - the ideas of "sci-fi" authors were an important element in the process of formulating needs, initiating breakthrough inventions, technologies, machines or devices. A spectacular illustration of such a process is the way from the ideas described by Jules Verne to Apollo 11 mission.

Speaking of "Engineering of Needs", one can be tempted to isolate in action sequences concerned with the need for specific phases of such activities and to assign such phases to corresponding names of these phases. According to the author of this study, specific tasks related to need can be described as follows:

1) Identifying existence of the need (**IP**) (objectively or objectively?)
2) General description of the need and its sources (**OOP**)
3) A detailed description of the need (**SOP**) with details of the process of meeting it) in terms of possible scenarios/variants
4) Evaluating effects of meeting identified needs (**OSZP**) as a basis for selecting the most appropriate scenario (due to the criteria adopted?).
5) Clarification of the needs description (**DOP**), including the assessment of the effects of its fulfillment for the needs of the next stage of the process of meeting the needs

If we assume that the above-mentioned tasks form a serial sequence (performing each task is a condition for starting the next task), an attempt can be made to show the sequence of activities related to the need in the form of a model, similar to the model of the process of meeting the needs, as presented in Fig.2. The graphic presentation of this model is shown in Fig.4.

Fig. 4. Serial model of the process of identifying, describing and evaluating needs

Undoubtedly, the model shown in Fig. 4 is very simplistic and does not take into account many issues, such as, for example, other than the shown couplings between the phases of the cycle shown. It is probably justified to assume that in the sequence of actions that comprise the process shown in Figure 4, it is important to take into account the impact of the outcome of each stage of the process on the earlier stages. This effect, which creates a network of feedbacks (as shown in Figure 2a), should also be included in this model.

This issue, as well as other issues not addressed in this paper, which are related to the concept of process definition of "needs engineering" (e.g. participants in EoN processes, risks related to actions and decisions taken in the process of EoN) will be the subject of further study by the author of this study.

IV. Engineering of Needs versus Technology Assessment

The problem of multi-faceted assessment of new and emerging technologies, products and services, especially in the context of the non-technical effects of the emergence and functioning in the lives of individuals, groups and communities of such new (innovative?) components of the wider human environment is increasingly often a problem in multi-disciplinary scientific research.

In particular, scientific society try to investigate the shaping by technology the reality in which a modern person lives and functions. To answer the question, what is the impact of engineering products on live of individuals and societies is an essence of a research area commonly referred to as the "Technology Assessment (TA)". Both attempts at defining the substantive framework of such a specific area as well as the examples of the use of various methods and tools for the mentioned purpose are presented in many various publications ([12], [13], [14]).

It seems that one of the issues that should be mentioned in the context of performing the tasks related to the above-mentioned technology assessment is to determine the purpose (need) of such assessment. According to the author of this paper, prior to the commencement of the sequence of activities comprising the process of evaluating products, services or technologies according to TA assumptions, not only general reflection but also more detailed preparation actions ought to be warranted. The demand for such preparations may be justified in many ways, the most obvious of which - according to the author - is due to the current state of technology and technology development. The basic question we should answer is:

- **whether the evaluation / evaluation should (will?) be carried on for all existing (and future) modern technical components creating our environment ?**

If the answer to this question was not clearly affirmative, the obvious question becomes the need to answer the next question:

- **Which of the existing or prepared to introduce into the "circulation" of products, services or technology, should be subject to evaluation within the TA process (and why are these fits?)?**

It was not until the next question that we should make a decision about the methods and tools that can be used in the TA process and the question of how such evaluations are used.

In the present state of our knowledge, we may point to only a few areas of technology in which the task of evaluating technology is either a requirement for specific procedures and regulations (as is the case in the area of health technology assessment, ie, the Health Technology Assessment (HTA) or in the field of Environmental Technology Verification (ETV) "([15], [16], [17]).

It is therefore worth asking here the criteria that can be used as the basis for the decision to submit products / technical means, technical services (including technical elements) or technological processes to be evaluated according to the TA concept. The author of this paper is of the opinion that - as is also apparent from the published work in this area so far - the above criteria or decision-making criteria can and should be derived from the following areas:

1. **History of technology/technology development: a significant changes in sources (origin) of needs**
2. **Technical progress: increasing the complexity of artifacts, environmental requirements (eg infrastructure, logistics), but also access to raw materials and/or business partners etc.**
3. **Technical revolutions: turning points also in terms of needs**
4. **Evolution of the role/participation of humans in the creation and use of technology.**

Also, in the case of needs related to TA processes, further research is necessary, in particular on - related to identified requirements - methods and tools used in TA activities. A separate issue, but, in the opinion of the author of this study, still underestimated, is the widely understood problem of training specialists in various fields (both technical and non-technical), prepared to identify, describe and assess needs, and to address performance needs identified in the light of identified needs. products, processes and technology

V. Conclusions

In the current state of technological development, taking into account both the pace of development and the disappearance of barriers to such development, which is connected primarily with the avalanche progress of human knowledge about the world and the opportunities for shaping the world, the suitable approach to the problem area of recognizing and satisfying human needs is of particular importance. According to the author of this study, this area of problems should be both a growing field of interest for researchers and a particular concern in the education of successive generations.

On the other hand, in the current state of knowledge about a rather specific area of action, which is undoubtedly the process of evaluating products, processes and technologies in the context of their social interactions, according to the "Technology Assessment (TA)", it seems reasonable to look for new research models, methods and tools that offer new opportunities, potentially widening the area under investigation. According to the author of this study, the above-mentioned postulate may be related in particular to the TA's view of problems related to - as broadly understood as possible - needs.

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