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CHANGES IN DESIGN ENGINEENER`S ETHOS – NEW IDEAL OF TECHNICAL DESIGNING

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1. Introduction

The title question, "What is today designing?" has wider implications: what values, standards, patterns of behaviour make up the style and standing of the group of persons referred to as designers? It is, therefore, a question concerning the ethos of the profession of the engineer designer.

The above-asked question can be confined to refer only to the scope of knowledge, skills and to the corresponding responsibilities, i.e. competence of this professional group. The trouble to find the answer to the question stems from the labour division in the designing team. The competence pyramid in a typical, for the present time, team work requires not only personal competence but, equally importantly, social, methodological and technical competence of the team as well as the board realising a specific project (Fig.1).

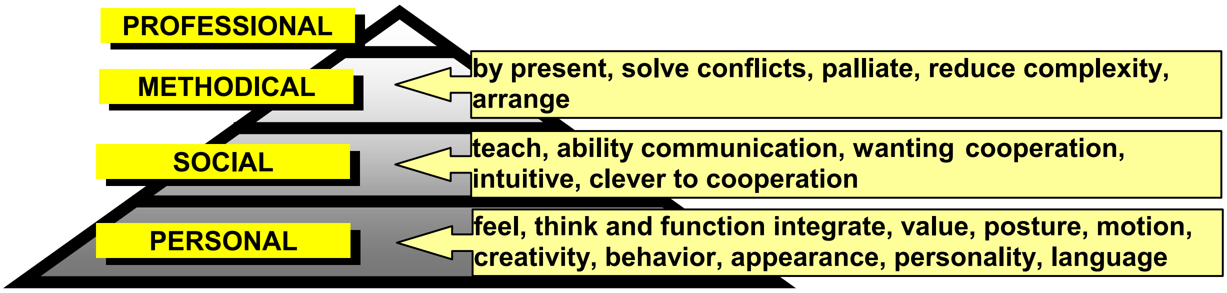

Fig.1. The pyramid of competence at team project work

Each of the applied labour divisions in the design team goes far beyond traditional principles of labour division. This division can be directed towards the process side (phases of the development process or sub-tasks in a problem), towards the subject side (required properties of the product) or organisational aspect (hierarchy of the labour division). Each designer, as a member of a team who is a team leader or a generalist or narrow specialist/expert in a given area or a young designer, participates in the team's creative negotiations, is motivated and assessed by the leader. Frequently, he or she has different education, experience, ways of action and understanding of various tasks and the surrounding world.

The study seeks to find answers to several questions: (1) is designing an applied science?; (2) is it a field of engineering art?; (3) or it is, perhaps, a field of craft?

The new ideal of designing and new designers' ethos in the society of knowledge should be defined more precisely than in the old remark of professor W. Gasparski, who claimed that "designing is an art for an artist, a technique for an engineer and a science for a pedagogue" [Gasparski 1988]. The biggest change in this society will be the change in knowledge, in its form and contents, understanding, in its responsibility and in what it means to be an educated person – prepared for life and work in two cultures: "intellectual" (abstractions, notions) and in the capacity of "a managing person" (people and work) [Drucker 1999].

2. Essence of designing

Questions about the essence of designing are not original [Branowski 2005a,b]. Answers to these questions can be found in papers of prof. dr hab. mult. dr h.c. Zb. Osiński and prof. dr P. Dietz. Summing up these papers, it is possible to observe differences in the approaches of the two scholars in their attempts to find answers to the question.

Professor Zb. Osiński [Osiński 1998, 1999] maintains that art, science and craft are *inseparable* in designing. The *element of art* understood as the creation of the abstraction by the creator combines the work of the artist over the piece of art and the designer over the image of a material product (machine, a piece of equipment). The *scientific element* is apparent in the feed back of the set functions by the material product with natural laws in a scientific description. The *craft element* in the designing process can be found in the designing heritage, in other words, from the lore about earlier tested constructions, possibilities of manufacture, material properties and other requirements (e.g. patents, regulations and costs).

Professor P. Dietz [Dietz 1996] conducts his considerations about designing as an art and craft on the plane of development of the designing science in which he actively participates as the pupil of professor G. Pahl. In his opinion, art and craft are also inseparable elements of designing. The *artistic element* stems from creativity, from its indispensable aspect of liberating the artist from blockages or initial fixations (not leading to the goal) and resulting from earlier professional experiences or cultural environment of the seeker.

The element of craftsmanship in designing arises from different methodical ways: (a) methods of supporting creativity; (b) methods of analysis; (c) methods of opinion; (d) structurisation of methodical approach to the process of task raising; (e) decision making.

3. The new ideal of design-engineering

The new ideal of design-engineering must take into consideration the variety of technical phenomena in constructor work. It is assumed that the theory of engineering based on system models and technical functions of work and activity will let to show it better. This new theory of technique forces a systematic approach to integration of different areas of knowledge to great extent arises from changes in the technology itself. The rise of importance of process conception of knowledge with regard different interactions with people and surrounding in the whole cycle of integrated design-engineering is shown in table 2. It means leaving the elementary paradigm in technique.

Tab. 2 Change of ideal of technical sciences

PARADIGM elementary	*PARADIGM integration*
Complexity reduction	complex integration of different science areas
View that integrity is constructed from elements	System approach
Work out of measurable and digital properties	impact on people and surrounding
Obtaining properties by analysis	Impact on processes and lifetime of a product
Analysis as a way of obtaining knowledge abort essential properties	Influence on synthesis of systems not on their analysis

From above changes in techniques derive new approaches to constructing. Engineering of systems, methodology of constructing, methods of planning and evaluation of future products as well as economical, social environment and humanistic context integrate creation, usage and elimination of products.

Views on design-engineering are derived from features of *construction science* [Pahl 1984, Eder 2005]: (I) substituting intuition and experience by using programmes, algorithms, questions, control lists; (II) system approach or usage of abstract models and methods of acting according to which they can be optimally planned, shaped, used and eliminated systems (e. g. machines, mechanisms).
In such approach *projecting science* [Hosnedl 2006] (used concept in the research exchangeable with science of constructing) includes [Eder 2005] theoretical issues of technical systems theory and theory of processes projecting and practical issues of knowledge of these systems (Fig.2).

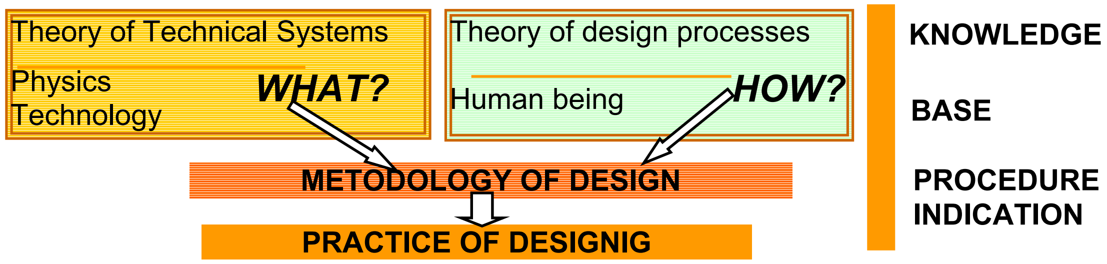

Fig.2 Areas of knowledge of science construction

The *theory of the systems* concentrates on their general nature, structures, taxonomy, properties, evaluation for decision taking, modeling and representation, life cycle of systems and their development in time. Whereas the theory of processes contains: (1) approach to creation of engineering processes, their structure, evaluation and classification; (2) acting on operators; (3) acting on design information; (4) management of processes and staff
Learning and teaching of design-engineering must be based on: (a) *the art of designing* containing transmission of general knowledge and skills of designing to technical systems and theoretical and practical knowledge; (2) *units of special technical systems* containing object knowledge and abilities to designing them; (3) *modeling* as competence for representing and experiment with technical systems for providing function of communication, information and visualization; (4) special information, data and knowledge used for realization of different properties and characteristics of technical systems (e.g. Design for X).
Of course the basic rules of design-engineering like: “from whole to detail”, “from single to complex” and “from known to unknown” are also obligatory.
Information and knowledge used differ in engineering disciplines. On this basis one should spot progressing autonomy of design-engineering. For example known from subject literature “island” set structure of object knowledge of design-engineering and their mutual connections V. Hubki [Hubka 1976]. Fig.3 shows “islands” of methodical knowledge of design-engineering. Mechatronics has become currently a separate branch of knowledge.
When accuiring new knowledge we use the one we already posess. From that point of view we can devide knowledge according to Rodenacker [Gawrysiak 1998] for:

(1) object knowledge = declarative showing description of technical targets (construction, principles of functioning and utilizable properties), the problems of shaping production and usage of machines (Fig3);

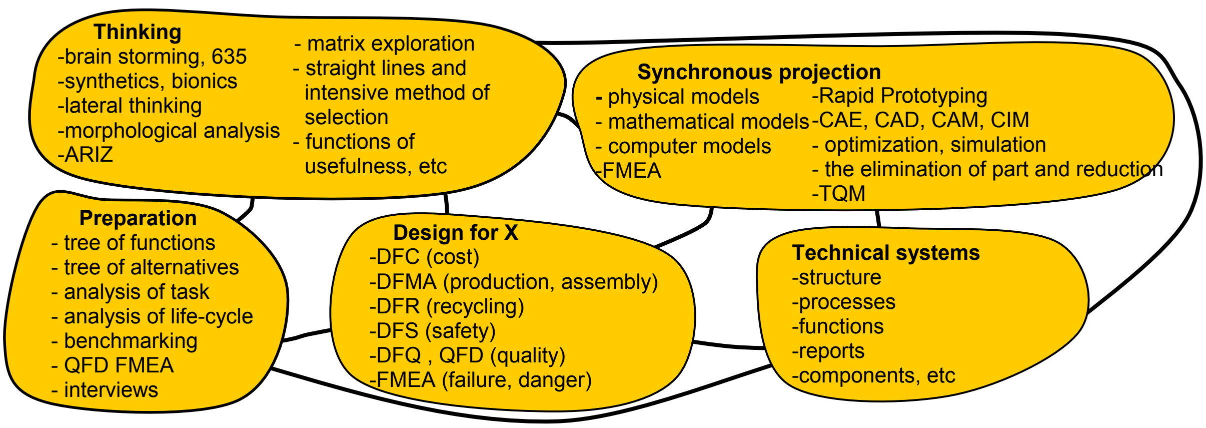

Fig .3. „Islands" of methodical knowledge

(2) methodical knowledge (providing solutions) and contextual (providing associations, simplifying usage of object knowledge), which contain basic knowledge about methodology and design-engineering techniques, constructing, production and utilization (Fig.4);

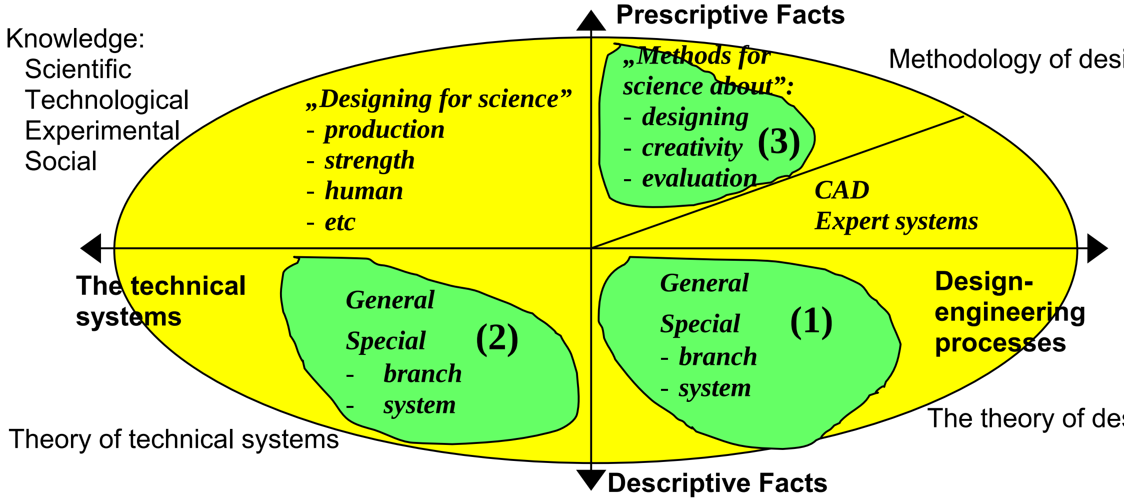

Fig.4. Dimensions of design-engineering science

(3) knowledge about techniqes of creativity, decision taking, value analysis, CAD systems, cost rules;

In this lengthy philosophical-mathematical- Natural Science-cognitive approach, the art of design-engineering is brought to objective and accessible for everybody procedures. The concept of *methodical design-engineering* is ment as planned procedure based on usage of methods and means appearing in each construction task [Gawrysiak 1998] (Fig.4).

The results of research concentrate around three appointed areas: (1) supplement of user processes by the theory of the systems; (2) classification of user and his relationship with a product; (3) opinions of user for supporting synthesis and creating work. Relationship of processes, methods, tools and surrounding is contains paradigm PMTE (Fig.5).

		PROCESES		
Supported by	▼		▲	**Supported by**
		METHODS		
Supported by	▼		▲	**Supported by**
		TOOLS		
Supported by	▼		▲	**Supported by**
		ENVIRONMENT		

Fig.5. Paradigm PMTE

The process uses methods subordinated to each stage used supported by tools which may need supported by surrounding in which they may be employed.

Taking into consideration current personal, organizational and computer integration of development of products and processes only two teams i.e. synchronous and quality guarantee (Fig.6) contain overall system approach to design-engineering.

They answer market challenge and match competition via shortening the time of development of product, reduction of costs of production and quality assurance. Concurrent engineering as systematic and integrated approach to design-engineering and exploitation enables gain mentioned above effects.

Discussion about meaning of the essence of design-engineering concerns relationship between knowledge and utility. Knowledge doesn't mean skill of doing something that means utility. The times of fast development of mechanical inventions between years1750 and 1800:

- on one hand invented technology, encouraged to usage of knowledge, improving tools, products and processes, to prizing innovators and spread their innovations,
- on the other hand they finished with mystery of craftsmanship, transforming experience into knowledge, apprenticeship in writing books, methodology and usage of knowledge.

It was the “energy industrial revolution” which caused transformation of society and civilization via technology and concentration of production.

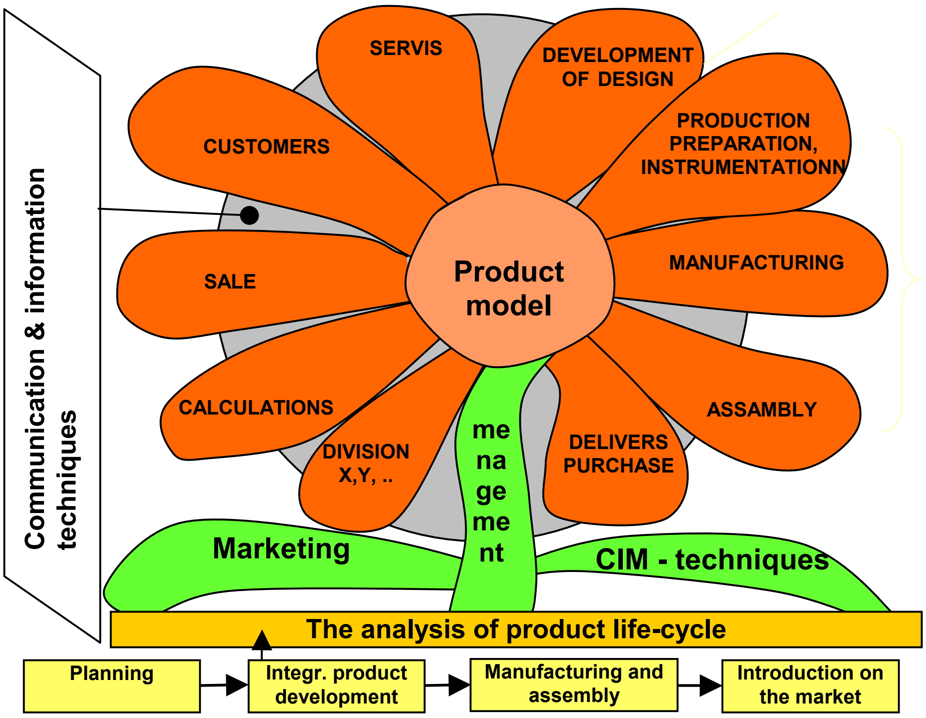

Fig.6. Concurrent engineering (according to [Dietz 1996])

In present society of knowledge (during computing revolution) exist 3 new applications of knowledge:

(1) permanent *improvement* of process, product and service (e.g. kaizen) that means process of team work on improving something significant),

(2) *exploitation* meaning permanent usage of former knowledge to create new and different products and services

(3) real *innovation* [Drucker 1999].

Currently a challenge is not technology but answering the question “what use it for?” The methodology of defining problems may be currently more wanted than methodology of solving problems. Research and development progress is developing in two directions: on the basis of new scientific knowledge arise new products and methods (basic innovation) and on the basis of new needs arise new knowledge (applied knowledge).

We also need methodology of transformation of specialistic information into action possibility, in conversion from nonproductive descriptive information into specialistic instructive knowledge. As far as creativity potential is concerned and process convergence the methods of design-engineering can be divided into: creation-, innovation-, routine designing (Fig.7).

„divergentional”	„convergentional”	
CREATIVE DESIGNING (total exchange of idea, new concept)	INNOVATION DESIGNING (realisation of a new idea)	„innovation”
REDESIGN (improvment of solution)	ROUTINE DESIGNING (change of data of known conception)	„adaptive”

Fig.7. The methods of designing.

Beginning new innovative design-engineering an engineer or designing team must perform marketing investigation, next use computing support in designing, production and usage to create high quality product. This support of knowledge is important when taking decisions of high risk and for shortening of design-construction cycle as well as extension of a product usage [Cempel 2003]. In creative thinking except for *professed knowledge* acquired during studying and practice (e.g. basis of knowledge, data basis, models) we need *intuition* that is direct hidden knowledge about something without information about its source not preceeded by analysis and reasoning.
Intuition was described by Einstein: ”On the way to discovery intellect has hardly anything to do. There happens a leap of awareness; call it intuition or as you wish, and the solution comes to you, and you don`t know where from and why.”

4. An attempt at the synthesis of the ethos of designer

Designer as an artist. *Designers talk about themselves that they cultivate art*. Rudolf Ch. K. Diesel once said: “The greatest thing for the engineer is that he can give shape and design in the same way as the artist”. “Art is the domain of questioning the reality, of describing the world not as it appears, but as it may be” (words of an outstanding Polish actor and theatre and film director, Andrzej Seweryn).
Creativity in the field of technique is conditioned by personal characters of the designer: the capability to predict without resorting to reasoning (intuition), instinctive shape harmony (imagination), agility and fluidity of mind allowing spontaneous transformation of experiences, observations and thoughts. A designer-artist employs elements of his engineering genius in new actions or new ‘works of art’. Due to his/her innate predisposition, perception capabilities and reasoning flexibility he can dig out grains of truths from images created in his imagination which had not been associated before. New images and ideas develop in the minds of people equipped in “a creative gift”, i.e. those who posses a sharp sense of observation, intuition, imagination and reasoning suppleness. An irrational capability of association of knowledge and ideas is more important than intelligence. Other important qualities include: practical flair for functional discoveries in technique, creative activity in setting up and solving problems as well as perseverance in pursuing goals. Experienced engineers maintain that excessive preparation of actions as well as disproportionate knowledge hinder creative work (e.g. searching for sources) and put ‘a safety jacket’ on creative designers. The mind should be free of limitations, stereotypes, habits and mental conventions.
It is difficult to find the above-presented picture of the *ideal person – creator*, partially artist and partially genius, in times when the profession of the designer is so widespread. To a limited extent, the artistic dimensions can often be found in the style of behaviour of designers, which can be characterised as: (1) originality, flexibility and fluency of cognitive processes; (2) ingeniousness, strong ‘ego’ and creative non-conformity; (3) productivity and self-realisation. The creative potentials of the individual should not be limited by the team work. The “creative team attitude” alongside “creative discussion” and maintenance of group individualism all constitute the basis of the creative enthusiasm and faith in success, provided the members of the group give up their rights to the property of ideas and ignore various prohibitions.
Creativity is not an unambiguous notion. It refers both to the recreation of the unknown reality (natural phenomena, discovery of natural laws) and to the creation of new things (e.g. works of technique). It is associated with a qualitatively new creation (work), in other words the object of creation (new shape, new arrangement and novel way of utilisation of a phenomenon, a new method of work or production). Without creativity at the entrance to the process of solving technical problems, there can be no success at the exit, no matter what technical means are used on the entire road (“garbage in – garbage out”). In order to increase the creativity, it is advisable to free the designer or the team of designers from creative restrictions or blockages. This means that the designer has the right to loosen the safety jacket of the ‘wishes’ type, while maintaining restrictions of the ‘demand’ type, when

re-defining the problem. Otherwise, the psychological obstacles of creativity such as: incorrect mindset on a specific direction of search or functional fixation connected with the allocation of the function to an object will make it difficult to apply the object in a different way. The process of searching for solutions is hindered not only by insufficient factual or methodological knowledge but also by complexity, conflictual nature, netting and objective dynamics as well as the intricacy and indivisibility of the designing object or the small number of variants of possible solution (in addition, in the close neighbourhood) and a propensity to "stick to the known". The choice of solutions may be wrong due to the formal reasons of accepting false criteria or assigning to them mistaken priorities or because of the absence of property analysis. Aesthetic criteria typical for art are employed in judging design. Frequently emphasis is placed on intuition as one of the ways of developing creative solution of design problems, especially at the stage of formulating concepts. Ingenuity, intuition, inquisitiveness, 'common sense' are among universal skill of a well-developed designer often hidden in his professional experience.

Designer as a craftsman. *Other representatives of technical professions describe designing activities as craft or try to find other caste designations ranging from science to computer craft.* Designing as a craft employs techniques – practical skills – for purposes of modelling, simulation or experimentation .There are a number of simple, standard and previously solved problems which can be unravelled easily with some experience, ability to cooperate with other people, ability to assimilate new ideas and not giving in to pressure. In every project, there is an advantage of routine realisation elements over the creative ones. A designer – craftsman (in the good sense of the word) substitutes the authentic creativity with his methodical, structuralised and analytic activities, wide analysis of the problem and the application of methods supporting creativity and utilisation of evaluation methods. This procedure is fully applicable in the area of the most frequently occurring adapted constructions (over 55% of constructions in machine design), i.e. those, which were adapted to a new goal without changing the principle of the technical solution or in multi-variant constructions (about 20%) consisting in the developing of new variants or arrangements without changing the function and solution principle. In the case of new constructions (25%), employing a new technique principle of the solution as well as in innovations, methodical construction is a tool which stimulates the inventive and cognitive mind of the designer, a generator of solutions facilitating the computer aid.

The great hopes accompanying the development of methodical designing and computer aided design are not easy to fulfil. There is a considerable distance between "what is" and "what should be", especially when it refers to problems requiring creative solutions. Designing possibilities and results depend on the interdisciplinary and integrated merger of human (needs), technical (feasibility) and business (remaining on the market) factors.

From the methodological point of view, designing is a conceptual activity in which we try to meet the demands in the best possible way at a given moment in time [Pahl 1984]. The above definition can be slightly widened: "*Designing is an activity* which utilises the achievements of natural sciences to seek solutions of a technical problem which takes into optimal account material, technological and economical constraints to determine unequivocally the construction and the way of utilisation of the designed object". The following thoughts are contained in two parts of this definition:

(1) The design task needs to be defined and set within a framework suitable for mental solution. The result of this part is a concept, i.e. a mental solution of the problem. Different methods of the mental 'break up' of the task can be applied.

(2) The process of solving of the task requires the identification of difficulties unfriendly for the problem solution which can be associated with the transfer of mechanical loads, with feasibility, i.e. manufacture and assembly, with the utilisation of the product and its price in relation to market competitors. This part takes up majority of the designing time.

(3) The designing activity is connected with processes taking place in different areas of the product development and with human involvement in these processes.

The increase of interest and development of effectiveness of design methods do not always walk hand in hand. Sources of success and failure of designers have always been the same.

This is confirmed by literature studies of the authors carried out on successful and unsuccessful air, weapon and other military constructions from the period of the 2nd World War (Table 1) written down in the basic and derivative records of the success or failure of the construction.

Table 1. Successes and failures of military constructions from the period of World War II.

CAUSES	
CONSTRUCTION SUCCESSES	**CONSTRUCTION FAILURES**
-unconventional project (first in the world, visionary, novel or somewhat fantastic; -ambitious construction (unconventional features, known concept reversed); - simplicity of mechanical system (small weight, low consumption of deficit materials); - sturdy construction (elimination of defects of the existing construction, utilisation of extinct patent, new construction utilising manufactured systems/parts); - new unprecedented production method (simplification by mutually cancelling production irregularities);	- revolutionary project, ahead of its times (support of big companies and politicians) - unreal demands (demand by the manufacturer or orderer for unreal parameters, targets for specific applications not fulfilled, economical problems), - failed concept (fantastic but crazy idea, correct concept but only for laboratory model, unclear negative action, main property dependant on many factors); - no possibilities for implementation (utilisable but no applicability, new problems all the time during experimentation, haste during experiments, required access to aerodynamic tunnel, series of failures during tests, social protests against tests, high implementation costs, high dynamic loads, movement resistance difficult for prognostication, short time for implementation, complicated handling procedures); - serial production of an unchecked model

Therefore, our approach to the problem of compliance and applicability of methods should be marked with moderation. They constitute the introduction and basis – for the learner, assistance and example – for the teacher, whereas for the practical designer – information, supplementation and assistance in further education [Pahl 1984].
The treatment of a design worker as a constructer is the result of a simple transfer of old standards of guild artistry to modern conditions [Gasparski 1988].
The design worker has knowledge and skills developed by the process of specialised education and practical training and has mastered, to a certain degree, methods and techniques (routines) of designing. However, the necessary condition of good work of a designer resulting from his/her acquired skills in applying appropriate techniques and methods, in themselves, do not guarantee the good result of the project. Rules, regulations and methods constitute a form of the designer's protection, especially the young one, against errors and failures and should not be treated as a muzzle put on the creative thinking.
Naturally, there is no need to demonise the importance of creativity. It is evident from the analysis of the types of creativity (Table 2) that two types of creativity, which cover the majority of the population, provide sufficient potentials of cognitive, emotional and motivation processes to produce new ideas (fluid creativity) and allow individuals to develop ideas driving them to attain goals and obtain skills needed to solve a definite class of problems in the course of the so called 'creative insight' (crystallized creativity).
Designer as a scientist. "Designing" has yet another meaning for *university lecturers*. Advanced reflection on the nature of designing and dissemination of these thoughts and considerations in the process of teaching and in publications as well as on conferences by several generations of professors of technical universities who frequently had been earlier involved in practical designing resulted in the development of well-organised knowledge about designing which takes into consideration intensive labour division and rapid development of construction and process design based on basic sciences and computer assistance. The knowledge about designing comes from the experience of designing practice, reflection from the processed experience of designers and scientific knowledge, i.e. reflection over designing conducted scientifically. Technical designing is the case of "designing in general", just as technical sciences can be defined as "science in general". General designing is a construct, that is to say a multidimensional notional construction

which possesses an empirical base in real designing processes as well as a theoretical base in the general methodology and in the science of science of applied disciplines.

Table 2. Types of creative work

CREATIVE WORK►	FLUID	CRYSTALLIZED	MATURE	OUTSTANDING
HEART AND SENSE	Development of different ideas	Solving a problem or achievement of objective	Solving and achievement important problems	Revolutionary change
COGNITIVE PROCESSES	Divergent thinking	Recognising a problem and change of problem representation, criticism of thinking	Utilisation of knowledge within one discipline	-
DESIRABLE INDIVIDUAL FEATURES	Fluidity, flexibility, originality, openness	Independence	Independence Tenacity	-
EMOTIONS	Interest	Driving emotions	Change of mood, depressions	-
MOTIVATION	Spontaneous	Task-oriented	Spontaneous	-
SOCIAL ASSESSMENT	Unimportant	Fairly important	Very important	All-important
CHANCE OF OCCURRENCE	Very high	Considerable	Small	Negligible

The content of the practical science about designing is not direct designing but theory of designing in various fields of human creativity and work.

Designing activities can proceed along two pathways: along the path of experience – individual, as a rule – and along the path utilising scientific methods of analysis and design improvement, when designing is simultaneously a science, learning and training.

The characteristic feature of the scientific approach is the application of scientific methods of analysis: formulation of requirements, aggregation of partial designing concepts into a general concept of the system, data development, interface definitions and component selection. Design methodologists and psychologists maintain that the following three analyses are essential for further development of the science of designing: (1) a*nalysis of the designing activity*; (2) a*nalysis of the design structures*; (3) a*nalysis of psychological effects*.

So the image of a person involved in the science of designing can be presented in the following way. A typical designer is both a generalist and a specialist with a comprehensive knowledge and competence concerning the subject, object and process of designing in a given field. He/she is interested in a wide range of problems: (1) descriptions of the designing process, designing models and their evaluations; (2) methods of problem solving (sets of methods, comparisons, evaluations, choices); (3) methods of developing ideas (heuristics, rational methods, creativity, computer methods of creating and processing information, testing ideas on models); (4) decision making (psychology, theory of assessment, selection procedures); (5) interrelationships man – machine (ergonomics, safety, aesthetics); (6) system designing; (7) management of designing; (8) computer aided design; (9) methodology of design.

Because of the complexity and sophistication of the knowledge and extensive experience, this discipline is not available to everybody.

Summing up, an attempt can be made to present the ethos of the designer (Table 3) by tabulating characteristic features of the designer as an individual which were discussed earlier.

It is possible to agree with the assertion that art, craft and science are all intermingled in designing. However, it is not possible to agree that the main subject of designing – the designer – is “an actor, who - in different scenes of the designing process – performs roles of the artist, craftsman and scientist”. The vastness and complexity of modern knowledge and diversity of the required human traits call for the division of roles, which can be assured by team work.

Table 3. Characteristic features of the designer [Nęcka 2001]

ENGINEER DESIGNER AS:		
artist	**craftsman**	**scientist**
- creative gift; - openness; - independence (non-conformism); - synthetic mind; - psychotic streak; - increased self-assessment; - creative activity; - creative style of life; - creativity; - imagination; - intuition; - agility and fluidity of mind; - perceptive skills; - practical mind; - tenacity; - sufficient discipline knowledge (especially aesthetic preparation), but not too extensive; - spontaneous motivation.	- developed analytical skills; - knowledge and skills formed by education and practice, frequently to the level of expert; - knowledge of designing heritage; - high professional ethics; - command of designing methods and techniques, including computer aided ones (as a tool, routine, habit); - command of methods aiding creativity; - command of methods of decision aiding	- knowledge and competence from the science of designing; - knowledge about psychological effects; - substitution of intuition and experience by conscious application of methods of conduct (programs, algorithms, questions, hints, guidelines); - systemic approach (modelling of objects and methods of action); - generalist in the field of integrated designing of objects and processes (DFX); - high ethic qualifications; - knowledge of scientific theories, especially knowledge about physical and biological phenomena.

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