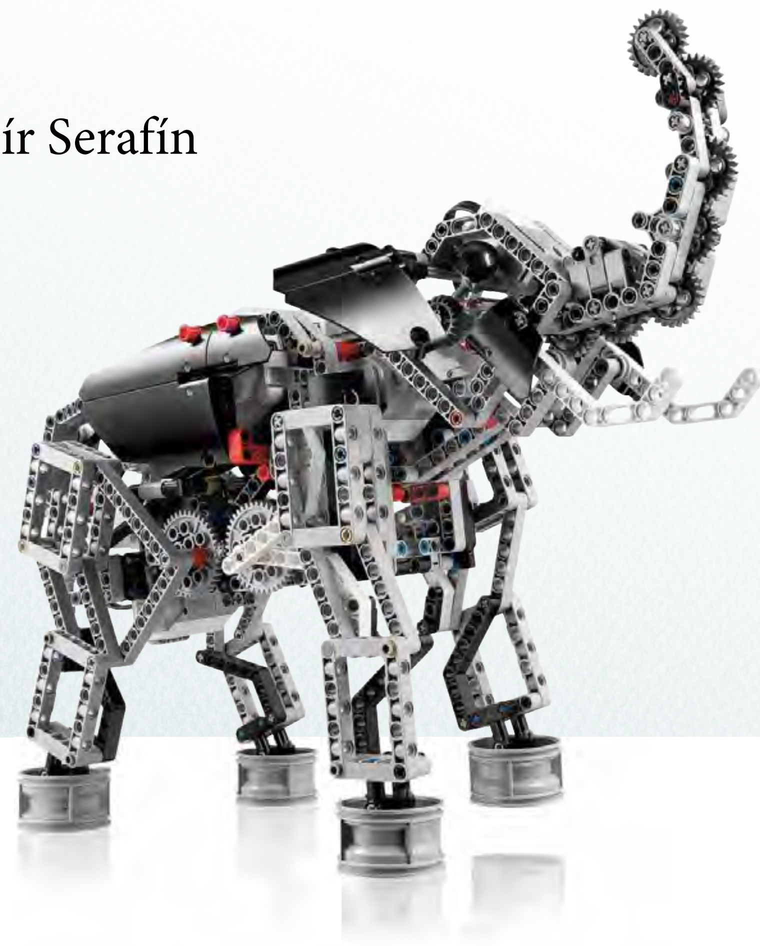
ILLUSTRATIVE ELECTRICAL ENGINEERING

in the primary school curriculum

Čestmír Serafín



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Foreword

Just like in the field of industrial production, changing the principles of technics used in the education system frequently means changing technology as well. At the same time, it requires significant qualitative changes in applied methods to be made, demands on teachers to increase, and thus different methods of organising work to be adopted. For pupils, education is a way to prepare for their future occupation, very often in working environments where the issues of management and regulation have become quite common. One day, pupils will take part in the processes of rationalising production and distribution, and they themselves will gradually become vehicles of rationalising management work. That is why it is appropriate to purposefully promote professional rules, methods, and aids as early as in primary education (1) so that pupils can actively form their own, correct orientation.

Teachers are the pupils' guides to education. Thus, their qualifications are crucial not only to pupils, but also to their own work in regard to knowledge and skills. Electrical engineering, or rather electronics is a field of study which forms the backbone of industrial production. Therefore, it can be considered a matter of course that in all areas of these fields, the teacher strives to choose a subject matter which would rouse the pupils' interest in the issue, not their aversion. When it comes to the above-mentioned fields, choosing the subject matter is a didactic transformation[1] and one of the most demanding tasks the teacher faces. Despite the inconsistency in quality and content, electrotechnical kits are aids–didactic tools which facilitate this selection by their ability to transform technical reality into a model, and vice versa. Technical equipment certainly can never fully replace a good teacher, but it can save time and energy which can then be used to develop the socialisation aspect of managing the guidance-education process.

Combining physical and mental activities as a prerequisite for a well-rounded personal development – that is the benefit of technical kits, electronic ones especially. Such combination also pushes the limits of the pupils' efficiency. When used correctly, the creativity of both pupils and teachers is developed on a superior developmental level of knowledge in terms of quality.

This process is also facilitated by innovations related to other scientific fields, such as cybernetics, system and information theory, ergonomics, bionics, developmental, social, and educational psychology (2), etc.

Electrotechnical kits have many positive effects in school education, suitably supplement as well as support it, and are also one of its subject matters. Considering the fast, global development information technology is experiencing, there is a growing need to combine computer systems and electrotechnical kits in education. This assists in the process of digitisation, too, which asserts itself in the conditions set for educating

[1] We are talking about the concept of didactically mediating educational contents which are, despite their variety, typical in terms of emphasising the choice of educational contents which take into account a pupil's (cognitive) skills.

children as early as in nursery schools. These facts thus serve as new stimuli for developing other spheres, not just that of education theory.

The goal of this monograph is to give a comparative and analytical insight into teaching general, primary-level technical subjects in the context of electrical engineering, especially of electrotechnical kits, and to define current trends in or approaches to the implementation of educational activities. The broader aim is to contribute to the development of the subject didactics of technical subjects, focused on younger pupils as well as educational practice.

We based this monograph on the following working assumptions:

- Pupils can form an attachment to electrical engineering in general technical subjects, taking into account the broadest areas of human knowledge, cognition, and utilisation. We also assume that this area needs to be developed precisely because pupils will work with technical equipment in the future;
- We assume that acquainting oneself with electrical engineering and getting ready for the life in a society equipped with technical means is an irreplaceable experience to pupils;
- The education's technical content is formed mostly as a result of transforming our knowledge of technics as a form of social practice. In view of the goals of this type of education, the technical content must be accompanied by didactically transformed viewpoints of a broader technical context, meaning electrical engineering as well (ecological, occupational, safety, economic, aesthetic, etc.). Thus, the technical (electrical engineering) content, as well as a wider guidance content come to play in education;
- In case of general technical subjects, guidance is an organic part of education. There are strong, organic, natural links between the technical content itself and a wider guidance content. Of course, this concerns electrical engineering, too;
- In teaching general technical subjects and those focused on electrical engineering, pupils' activities and their advisable implementation take priority. What is necessary, however, is a sufficient knowledge base which permits the development of technical thinking and technical creativity;
- Ensuring a good-quality education requires a systemic approach. This focus on teaching subjects with the emphasis on electrical engineering should be grounded in teaching documentation. Education must be implemented by well-prepared, enthusiastic teachers who are equipped with sufficient material resources and methodical support.

The goal of this monograph is to contribute to the area of teaching electrical engineering, especially by using electrotechnical kits as didactic training tools in contemporary schools, and to define what is required by this field in view of the goals of the teaching process, especially of the education theory. The study summarizes the issue of electrotechnical kits from the view of their application to the area of general vocational training, and formulates answers to some related practical issues of the relevant subject didactics.

One of the outputs includes the search for the definition of evaluative areas, rules, and requirements; of evaluating electrotechnical kits which enable us to clearly assess the properties of electrotechnical kits in regard to education needs. The text presents theoretical findings related to an analytical approach to and synthesis of the knowledge acquired in the chosen field. Thus, emphasis is mostly on conducting a classification and relational analysis of the relevant parts of the theory's content. This was the method for studying the reflection of the individual theoretical parts that constitute an education concept as well as requirements for general technical subjects with a special focus on electrical engineering. Both pedagogical and non-pedagogical literature and documentation were a subject of study.

The monograph presents the results of past research surveys which were conducted in relation to incorporating electrical engineering into education, and of the effectiveness of the implemented education in the practical reality of teaching which includes using electrotechnical kits as one of the basic didactic training tools in this sphere of technics. One subject of discussion also includes the condition/the current state of implementing education in the primary school environment. Last but not least, the outputs are summarized in Conclusions as a basis for determining the state of teaching electrical engineering in primary schools in the digital world that is the technosphere of our modern civilization.

Some individual ideas and insights presented in this monograph have been published in specialised magazines and thematic anthologies in the Czech Republic as well as abroad, mainly at international conferences where the author gained many insights which proved valuable to his own work in the field of pedagogy. Some of the examined issues played or play a part in fulfilling other research tasks.

Author

1 Introduction to the issue

The most visible example of electricity is probably a lightning cutting through the sky during a thunderstorm. Electricity is invisible in almost all other cases, and yet it keeps tirelessly serving us. Electric power (3) fuels machines, is controlled by various devices, provides light and heat. Signals which allow phone, radio-receivers, TV sets, or computers to work have an electric origin as well. But how should we outline this world to those who may encounter the manifestations of electric power daily, yet know next to nothing about its nature? How should we explain these phenomena to them? The dry theory we most frequently encounter in physics textbooks or specialised texts on electrical engineering (4), (5) usually does not address this in any detail. But what if we could physically "touch" electricity, to verify theories in other (6), more entertaining ways? After all, our memory best retains what we try and verify on our own.

From the point of view of schools, the immateriality of electrical engineering poses a challenge to concepts of education programmes and to relevant chapters in the textbooks and methodical manuals that deal with it (especially when it comes to the concept of general vocational training (7), (8)). The curriculum is heavy on experiments, and thus demands the presence of technical equipment in schools. That is why it is necessary to emphasise the importance of material and didactic training tools[2] which most definitely include electrotechnical kits as a part of technical equipment, and therefore vocational training.

1.1 Technics and education

In the current Czech education system, the concept of technology is interpreted as a matter of general vocational training and applied to it. In view of this, it is necessary to assume a corresponding approach to interpreting pedagogical rules and principles as they pertain to using electrotechnical kits.

The term ***technics*** (derived from the Greek word *tékhnē* – knowledge, craftsmanship) describes a vast, complex, hard-to-delineate part of the world we inhabit (9). Thus, it is rather difficult to formulate its clear definition. It all depends on one's specific approach to science and philosophy. This problem is felt not only in Czech scientific circles, but also abroad – the works of W. Walat (10), O. Autio

[2] Material didactic training tools can be defined as didactic training tools of a material nature. They are objects (or sets of objects) that serve a didactic purpose, i.e. along with the educational content or methods and forms have a direct effect on accomplishing the goals of the education process, or create suitable conditions for this effect to take place. (https://uprps.pedf.cuni.cz/UPRPS-440-version1-23_rambousek.pdf)

and R. Hansen (11), or A. Williams and J. Williams (12), as well as many others, can be mentioned as an example. There are usually two approaches to teaching subjects with a technical focus. According to J. Kropáč (9), W. Walat (10), and J. Stoffa (13), the substance of the term in regard to teaching technical subjects can be expressed in two ways:

- *technics* as a set of tools artificially created by human activities to the benefit of humans, and as an aggregate of methods and procedures employed while creating and using them. This concept has one disadvantage, though, namely the necessity to distinguish between two related aspects – the narrow approach (a set of artificially created tools), and the general approach (the processes of using artificially created tools, sources, power, etc.);
- *technics* refers to the aggregate of material, purposefully created objects and immaterial substances created by human activities. The way activity is implemented is then called technology. Both terms, technics and technology, are a part of technosphere – an artificial environment created by humans. This concept is based mainly on the works of J. Stoffa (14) and I. Štubňa, and at the moment greatly affects attitudes to education, especially in the constructivist concept.

It is understandable that technics is a social phenomenon since it, along with nature and society, creates and shapes human environment. According to J. Kropáč (9) whose works pick up on those by H. Wolffgramm, technics has certain specifics which can be described as manifestations of its rules:

1. The unity of natural and social moments in technics – the basis is a technical object, system, or procedure which uses natural phenomena and rules.
2. Determination of technics – technics is a tool to reach goals in the end–means relationship.
3. Complex nature of technics – a result of confluence of many natural, technical, and social rules.
4. Plurality of technical solutions – most of the time, a solution is not always obvious due to many active influences.

The use of technics is associated with the development of human societies and of social, intellectual, and physical skills of individuals. Thus, technics becomes a necessary part of solving the various situations and problems life brings. Schools, of course, react to this – by introducing vocational training into the education system, though this term is nowadays used in the figurative sense (practical activities, work guidance, the work world, etc.).

Traditionally, pedagogy has divided guidance into components (intellectual, moral, aesthetic, physical, and work ones) whose content addresses the interim goals of pedagogy (see Z. Kalhous (16) or H. Grecmanová (17), among others, for more details). These components include *work guidance* which can be understood as a framework for establishing a relationship to work and for acquiring general technical knowledge, skills, and habits (8), (18). It is implemented by the practical focus of school subjects, by field trips, and leisure activities. Because work guidance deals with acquiring general technical knowledge, the term *technical guidance* is introduced.

According to J. Stoffa (13), vocational training can be viewed as a systematic controlled process of intentionally shaping one's personality as it relates to technics, in a way that makes sure that the person being educated has a correct attitude to technics and its use in their own life (a creation of the so-called technical literacy). These goals must be met on a scientific basis, consciously, and in the course of activities related to the technics which each person encounters as a part of their daily life, i.e. technics that may have an effect on the life of the person being educated. The content of this term lies in our understanding of the connections between technics, society, and nature. Therefore, the content of vocational training is rather universal and includes a wide range of technics as well as related activities.

By implementing vocational training, the following is created (9):

- knowledge of technics, its production and use;
- proficiency, habits, and skills in regard to carrying out activities related to technics;
- creative proficiency and skills in working with technics;
- positive relationship and attitude to technics and activities related to it.

Therefore, let us talk about vocational training in the broadest sense of the term. This does not mean a specialised vocational training which results in occupational qualifications, but a vocational training whose aim is to establish technical literacy (19), (20), (21). Among our experts, the main credit for developing the term *technical literacy* goes to J. Stoffa (22) who formulated the following requirements in regard to technical literacy as a competence:

- to be aware of the key processes in technics ("What is this?" and "How does this work?");
- to operate technical devices and apparatuses;
- to apply technical knowledge;
- to develop one's own technical knowledge, skills, and habits;
- to use technical information and evaluate it.

T. Kozík and M. Kožuchová (23) establish three elementary areas as the basis of technical literacy:

1. attitudinal – to understand the role of technics in society (to understand different aspects of technics), namely in view of these types of relationships:
   - economic;

- environmental;
- social;
- aesthetic;
- moral;
2. content:
   - awareness of technical terms and processes;
   - using technical tools;
3. procedural – mastering the methods and system of scientific research.

The term *technical literacy* is also defined in the work of J. Bajtoš and J. Pavelka (p. 36) (24), as follows:
- acquiring the knowledge of technics and technical materials, and gaining technical skills;
- competence in solving technical issues;
- establishing an intellectual relationship to technics;
- understanding the relationship between science and technics, and acquiring the skill to apply it;
- developing technical creative thinking.

Based on the areas of technical literacy formulated above, we can observe that the acquired technical knowledge helps pupils to correctly get their bearings, especially in situations where they encounter technics or a technical object and become its users. However, the knowledge also helps them in situations where they have to solve issues which result from the failing functionalities of technical devices–objects, or if they themselves would like to create an adequately challenging technical object or are supposed to take part in its creation. This concerns knowledge of technics as a part of human culture, of its importance for humanity, and subsequently knowledge gained from key technical fields – especially disciplines which deal with technical materials; the technology of materials; technical graphics; studying machinery as well as its components and mechanisms; electrical engineering and electronics; and last but not least studying cybernetics as well as information and communication technologies.

1.2 Constructivism in experimental academic work

The current concept of education, as well as modern methods and procedures, aims to take a proactive approach. Educational activities, nowadays supported by modern information and communication technologies in most cases, focus mainly on innovative procedures which are familiar to the current generation and allow it to better handle the vast areas of knowledge and skills it needs to acquire.

In our information (digital) society, it is necessary to develop the general concept of information literacy across all areas of knowledge. This concept requires an adequate adjustment of the education of future teachers, the fundamental vehicles which mediate knowledge to young generations. Without these modern approaches, quality training would be inconceivable.

Constructivism is a wide range of behavioural and social science theories, one which emphasises both the active function of the subject, and the importance of the subject's interactions with their environment and the society as such.

Constructivism is based on the process of actively constructing one's knowledge through their own activities and by sharing it with other individuals. Thus, the individual forms new experiences on the basis of their previous ones and as a part of their interaction with the environment. This creates a pattern which allows the individual to understand these new facts and incorporate them into previous structures. The constructivism's main starting points are (25):

1. The individual being educated actively constructs their knowledge. Learning is not a passive activity.
2. Learning can be both an individual, and social matter.
3. Learning is a self-regulating process. Each individual learns differently, depending on their own internal dispositions and on external factors.
4. Learning is a process of management which allows people to understand the world. From the constructivist point of view, equilibration brings stability and the internal cohesion of one's system of knowledge. New information may be subject to assimilation, i.e. new knowledge is incorporated into the existing pattern. Alternatively, if the new knowledge does not conform to the individual's experiences or original concepts, the process of accommodation takes place, i.e. a new pattern is created which is in line with the new information.
5. The function of knowledge is to organise the world of one's own experiences, not objective reality. Truth is viable, i.e. subject to a person's adaptation to the world. It helps one to survive in this world without necessarily being valid. The goal of learning is to organise and understand the world of one's experiences.
6. Reality means interpretation. Information is absorbed by the individual and reaches them through their own interpretation, not as an intact "truth about the world". This truth is created by the individual themselves; they construct it within.
7. Learning is a social-contextual activity, developed in a stimulating environment. The reconstruction of one's own knowledge, and discovery of one's own patterns can take place with the support from others.
8. Language plays an important part in the process of learning. Thinking takes place as a part of communication. Constructivists emphasise the role of language

as a tool which allows us to connect what we have already learned in the past with the results of learning, i.e. the very construction process which results in individual knowledge.

9. Motivation is a key learning factor. Rewards and punishments are considered external means of motivation. For constructivists, the chief source of motivation can be found in the internal (individual) need to understand the world and one's own knowledge.

The constructivist approach emphasises the following (25):

- the pupil's active participation is crucial;
- learning is the process of cognitive construction;
- the most effective way learning can happen is by actively handling objects, their models, etc.;
- any new learning begins by updating previous knowledge;
- learning is best induced in a stimulating, complex environment;
- creating significant problem situations supports the meaningfulness of learning and the motivation of pupils;
- social and cultural context is important if matters and phenomena are to be understood.

There are more constructivist schools of thought. The main ones include (25):

a) Cognitive constructivism is based on Piaget's and Dewey's conclusions that an individual who is in the process of acquiring knowledge connects parts of the information from the external environment into meaningful structures and performs mental operations which correspond to their own level of cognitive development.
b) Social constructivism (according to Vygotsky) emphasises the irreplaceability of social interaction and culture in the construction of knowledge. Education is a social process that takes place on the basis of human communication.
c) Radical constructivism includes everything that exceeds the world of the individual's experiences. The individual can form only subjective images of the world which reflect their own experiences, not any communicated truth about the world which they themselves have not experienced.
d) Personal constructivism states that there is no such thing as a passive receipt of knowledge, only active receipt as a part of the subject's learning.

Methods of pre-graduate preparation and the content of various disciplines on one hand, and the teachers' ability to systematically and clearly update the presented curriculum on the other place great demands on contemporary teachers in terms of expert knowledge and subject didactics. Such demands can be met only by highly competent teachers who have been prepared for their occupation by the tenets of modern pedagogy, one of them being the constructivist approach mentioned above.

Teacher competence requirements increase in proportion to the number of disciplines which are considered relevant to the teacher's occupation. A teacher must have undergone a quality theoretical and practical preparation not only in expert matters; they must also be psychologists as studying (especially when it comes to studying disciplines related to natural sciences or technical issues) places great intellectual and manual demands on pupils. The teacher's task is to combine a pupil's motivation with their individuality.

J. Vašutová (26) defines subject competence as a single whole where a teacher should master systematic knowledge of their specialisation to the extent and depth adequate to primary or secondary school needs; they should be able to transform knowledge of relevant scientific disciplines into the educational content of school subjects; they should be aware of methods to incorporate interdisciplinary knowledge and conduct cross-curriculum relationships; they should be capable of researching and processing information with the use of modern information and communication technology; and finally, the teacher should know how to transform the learning methodology of their own field into the way their pupils think. The future teacher can acquire this competence by studying their specialisation and its methodology, didactics, pedagogical psychology, and informatics.

Let us delve into practical competence which is closely related to subject competence and emphasises the specificity of teaching natural sciences and technical subjects. This specificity manifests itself when theoretical knowledge is connected with the practical (experimental) testing of its validity. That is why there is so much emphasis put on the application nature of individual disciplines, as well as on the skills of those who will one day teach specialised technical subjects or disciplines with a focus on natural sciences – an ability to independently and skilfully apply theoretical knowledge is of paramount importance. From this point of view, it is also very important to include disciplines which combine subject didactics with laboratory equipment. On one hand, this helps teachers develop their own psychomotor skills, and on the other introduces practical rules and points out problems which can be typically encountered when conducting specific experiments.

In terms of developing one's own thinking and the concept of creativity, the constructivist approach, based on motivated activities of those who study teaching, aims to invoke situations where students actively get involved in "reactions" with individual preconceptions. This mostly concerns an attempt to raise awareness of an issue, to invoke a sense of tension between an existing notion and a new piece of information or experience. However, this necessitates that the individual's intuitive ideas about a given phenomenon be first diagnosed, and experiences which cognitively clash with the idea then presented. In order for the cognitive conflict to be resolved, the individual must construct or discover new solutions. This can be very easily applied to the area of experimental work in school laboratories. The issue of "comprehension" is very important in this context, namely the processes which cause such comprehension to emerge. In the constructivist context, comprehension can be viewed as an interpretation of new information in view of existing knowledge (27), and also as a process where an individual mentally constructs the meaning and sense of what they know and perceive (28). Thus, comprehension means reworking and expanding a mental construct in view of so-called preconceptions, i.e. of one's experiences, knowledge, attitudes, and mental structures (29).

Teaching can be successfully implemented only if there are suitable conditions for establishing a complex educational environment where a pupil or student can and wants to successfully learn and where their accomplishments motivate them to continue studying. Establishing a complex educational environment is an educator's fundamental competence, one which conditions and expresses their professional proficiency and constitutes a part of the subject competence of future educators.

Therefore, it is necessary to prepare teachers of technical subjects or natural sciences in a way that is based on the synergy of specialised and pedagogical-psychological disciplines. If such a preparation is combined with the student's creative experimental work, it facilitates the optimisation of acquiring a didactic awareness of the teaching's content (30).

In the constructivist approach, the effort to combine the theoretical and practical parts of teaching often leads to the use of modern tools based on information and communication technologies, for example virtual on-line laboratories.

Remote experiments are a modern tool for conducting real-life school laboratory experiments, most often controlled on the internet, i.e. on-line (Figure 1.1). Compared to their traditional laboratory counterpart, these experiments have several, rather notable advantages (31):

- free access to a "remote" laboratory (anytime, anywhere);
- no need for aids, measuring tools, and other technical equipment;
- the possibility of repeating the experiment multiple times;
- work with real-life measuring tools, real-life data;
- quick and graphic data processing;
- no danger, no risk of injury;
- can be used for preparation at home, for distance education.

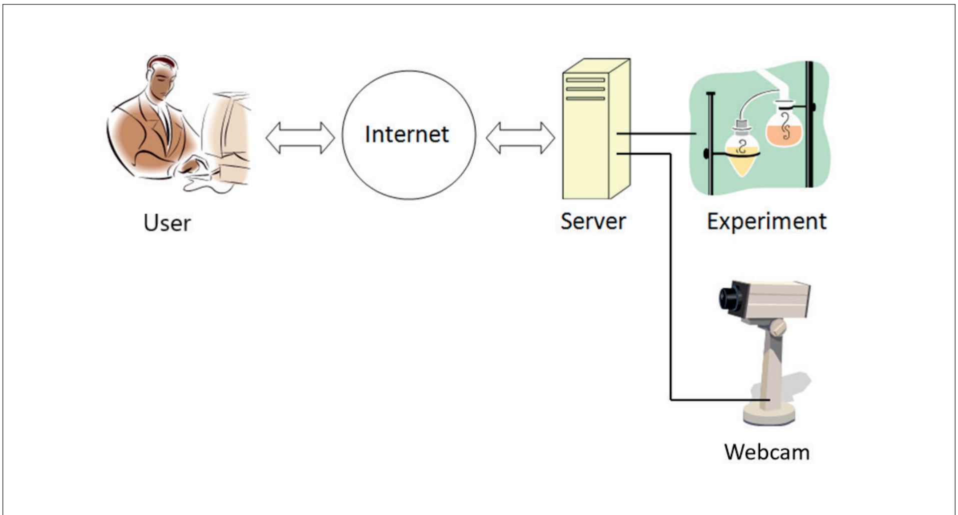

Figure 1.1 Solving virtual systems – remotely controlled experiments[3]

Ch. Levert and S. Pierre (32) present their own methodology, a general concept and modelling of virtual laboratories which must be safe, inter-operational, with quality services, and have to function in different configurations as well as on different platforms. At the same time, however, we cannot omit to mention that this must also include a model for educating future teachers that addresses their individual needs and is based on the goals and needs of future teachers–users.

The development of technical thinking is a fundamental goal of teaching technical subjects, regardless of their special focus. E. Franus (33), a Polish psychologist, analysed the important term *technical thinking*. His work was presented in the context of the former Czechoslovakia and then developed by I. Krušpán (34) who translated the definition of technical thinking, formulated by E. Franus himself, into Slovak: "Technical thinking is the process of reflecting and using physical laws as well as technical principles in technical creation and technological processes." This definition accurately describes the two related aspects of technical thinking – namely cognitive processes which are of a predominantly analytical nature, and creative or construction processes where synthesis prevails.

The above-mentioned aspects of technical thinking should also be taken into account when experimental activities for technical subjects are being designed. When it comes to experimenting in technical subjects, the fundamental logic and focus of cognitive processes is similar to those which are at play in natural sciences, though they must respect the broad social (economic, psychological, etc.), natural, and of course technical context (thus, abstraction is made more difficult). That is

3 Source: https://commons.wikimedia.org/w/index.php?curid=36909652

why current trends in designing natural science experiments serve as an inspiration to technical subjects. Here, attempts to exercise an explorational approach strongly manifest themselves. Studies with such a focus have been published, among others, by D. Nezvalová (35), M. Papáček (36), J. Dostál (37), and others. Undeniably, these attempts continue applying the constructivist approach to teaching. Experiments witch an explorational focus position pupils as "scientists or researchers". According to D. Nezvalová (35), over the course of education with an explorational focus or during experiments, pupils – based on situations invoked by the teacher – ask questions with an explorational focus; look for evidence; formulate explanations based on the evidence; evaluate explanations with the possibility of using alternative ones; communicate and verify the explanations.

The above-mentioned fully applies to the issue of experimenting in technical subjects. Such experimenting, however, wouldn't be perfect; rather, it would only support cognitive activities aimed at discovering usually basic, general technical context and relationships. Over the course of experimenting, mental creative or construction processes which constitute the second part of technical thinking are connected with situations, activities, outputs, or products that are more specific. What actually takes place here is, therefore, an application of synthesis of acquired knowledge to "a new quality of solutions" (at least from the pupil's point of view) and its experimental verification. In this case, nevertheless, situations should adequately include stages of the life of technical equipment, namely: recognising the need, designing, construction, programming (e.g. ensuring production by technological means), creation, use, and disposal (38).

Including pupils' cognitive activities and creation processes, as well as the solution to educational situations which consists in meeting the legitimate needs of an individual or a group, to the full extent of the creation, use, disposal of technics – all of that is generally the point of teaching technical subjects and should be supported by the pupils' experimental activities.

In accordance with the transformation of contemporary schools which emphasises, among other things, the teaching's focus on activities and experiences, it can be concluded that it is important to strengthen this concept in preparing those who study the teaching of general technical subjects, with the goal of better preparing them for their future occupation as educators. The starting point for making changes in the concept of teaching subject didactics in regard to vocational training is therefore a critical analysis of the current concept of teaching, performed by evaluating the level and quality of competence acquired by students of vocational training.

1.3 Technical thinking

Humans change and shape their environment mainly by means of technics. At the same time, they look for, discover, create, improve, and expand their environment and options (although the opposite can be true sometimes). They place an artificial environment, a material culture between themselves and the nature (13). All of this requires specific technical approaches, procedures, and methods of thinking.

The term *technical thinking* and methods of developing technical thinking in teaching are an important issue for the didactics of technical subjects (9). Theories which focus on the issues of technical thinking can be encountered in the foreign didactics of technical subjects, rather than in the Czech one (39). Nowadays, however, attention is predominantly paid to the term *creativity* or *technical creativity*. The term *technical thinking* is less common.

Technical thinking is a specific form of thinking; a term with a broadly defined content (naturally, since *technical* itself is a broadly defined concept). In practical situations, technical thinking and the related requirements must have a more precise definition. In our opinion, a pupil's technical thinking should be generally defined in accordance with the term *technical literacy*; this term was presented in the works of J. Kropáč (9), (40), for example. Based on the nature of technics, technical thinking has a variety of specificities. An unbroken continuity of theoretical and practical components is one such specificity; another basic one lies in the means – end relationship (finality), or in determining which means should be employed in order to meet a specific end. Here, one other fundamental aspect of technics and thinking is of importance – complexity, as no significant context can be omitted when working with technical equipment, regardless of whether such context is of a technical or non-technical nature. It is also clear that different means or technical options can be used to meet a specific end or fulfil a specific goal. In this case, the ability to engage in critical and evaluative thinking asserts itself.

Technical thinking includes such operations as analysis, synthesis, abstraction or concretisation, classification, and analogy (41). In connection with technical imagination, this mainly concerns analysing the notion of a product; activating one's existing knowledge, skills, and experiences which can be used to solve the interim issues of constructing and creating products; and finally synthesizing all applicable realities by means of which the researcher creates a project, i.e. arrives at the complete solution of constructing and creating a product. In this context, the works of a prominent Polish psychologist E. Franus (33) are worth mentioning. Franus defines technical thinking as a process which reflects and uses physical laws and technical principles in technical subjects and technological processes.

German authors B. Hill and B. Meier (42) also describe technical thinking as a mediated and generalised reflection of reality. It is characterised and predetermined by a close relationship between conceptual, visual (notional), and practical components of technical activities. It is indisputable that technical thinking consists of cognition and creation, of mental operations with the ideal reflections of objective reality. One characteristic feature of technical thinking is that it involves not only existing objective reality, but also options based on the system of social cognition. This can have different degrees and forms, from creating brand new objects or procedures, to their improvement or finding failures in them.

According to L. Tondl (43), the above-mentioned definition suggests that technical thinking has two related aspects:

- the cognitive aspect, which is an activity during the course of which we familiarise ourselves with the structure and function of new technical creations and drawings. This takes place during assembly or disassembly as well (the activity is therefore primarily of an analytical nature);
- the construction (creative) aspect, meaning a mental process focused on such creative activities as designing, improving, inventing, or solving technical tasks and processes (the activity is primarily of a synthetic nature).

Both of the above-mentioned aspects manifest themselves in the relationship to electrotechnical kits since the cognitive as well as construction aspect are an integral part of working with any electrotechnical kit.

When solving problems, cognitive thinking always has an auxiliary function of preparing one's intellect for a creative synthesis (33). Creative thinking thus picks up on the "content" of cognitive thinking. Both processes play a part in resolving problems, though they are not identical. If analysis is a fundamental attribute of cognitive processes in science and technology while synthesis is a basic characteristic of creative processes, it means that there is a psychological barrier between cognitive and creative processes which take place when we think; between analysis and synthesis, both in scientific and technical thinking. This is a permeable, transitional barrier which divides the process of thinking into two parts: the cognitive, analytical part, and the creative (construction) part. The permeable transitional barrier is sort of a Rubicon (33) we cross when thinking (intentionally or not) in order to acquire a new quality. This happens when the process of thinking gathers enough information and reflections, i.e. productive content, for quantity to be transformed into quality as per the laws of dialectics. This new quality keeps on "requiring a supply" of details, but already offers a hint of a solution to the issue. That is why the above-mentioned transitional barrier is at the same time a symbol of transitioning from analysis to synthesis, from quantity to quality, from the cognitive process to the creative one, from discovery to creative action. The issue of transition is therefore the issue of meeting the necessary conditions to resolve a problem.

Thinking aimed at resolving problems can be twofold (33):
- with a homogenous structure of a purely cognitive type, if this concerns an unproductive process, limited by the knowledge of the problem's content and not leading to a resolution of a new problem;
- with a dual structure, i.e. with a cognitive, creative aspect, and thus a productive outcome.

Mental work to resolve a difficult problem does not follow a simple model (it does not copy a simple model), but contains many synthetic micro-parts (micro-syntheses) which form a final creative macro-synthetic complex, like links in a chain. Apart from this, in multicomponental cases, a mental-cognitive creative or construction structure produces a "mosaic" which consists of multiple micro-synthetic parts.

According to E. Franus (33), technical thinking which asserts itself and is developed during the process of technical activities is:
- an integral part of a person's cultural maturity;
- a special kind of human thought;
- an activity involved in resolving theoretical and practical issues;
- a regulator of human activities in relation to technics.

Just like any other type of creative thinking, technical thinking is not only cognitive thinking, but also a two-natured complex process which respects both simple, and difficult issues, as well as the structures of micro-syntheses and macro-syntheses.

In scientific thought, creative synthesis is the crux of formulating theories as a part of scientific discovery; in technology, it is the core of inventing and creating the structures of technical objects. In both cases, we deal with concrete or concretised (object-oriented) processes of creative thinking, although the quality of these processes varies significantly. Both are developed in the sphere of concepts and notions, but the former always includes the form of words and sentences while the latter necessitates a depiction and specific material substance.

During the course of creative and analytical processes, cognitive thinking serves various functions. In scientific output, it works as a research process that prepares sets of information necessary for formulating a theory, or as a cognitive process which facilitates one's familiarisation with the content of the problems being solved. In technical output, this applies to at least four general situations: securing information in order to acquaint oneself with the problem's content; learning about scientific theories, technological principles, rules, etc.; examining the progress of production activities; examining the activities of the finished object. In each of these situations, the results of cognition (choices, decisions) are an act of creative synthesis and a key element for completing the creative process.