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DIDACTIC IMAGES AND THE UNDERSTANDING OF ELECTRONIC TECHNOLOGY

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Key words: understanding of technology, didactic images, electronic technology.

Abstract

The paper presents the recent state of research on the issues of understanding electronic technology, with emphasis put on the significance of didactic images in understanding. Theoretical considerations showing terminological convention and presenting numerous works in the field of understanding technology were supplemented with a presentation of results of the research on the efficiency of understanding electronic elements, systems and devices by grammar school students, following the introduction of various methodological techniques focused on the modernization of the form and contents of didactic images.

OBRAZY DYDAKTYCZNE A ROZUMIENIE TECHNIKI ELEKTRONICZNEJ

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Słowa kluczowe: rozumienie techniki, obrazy dydaktyczne, technika elektroniczna.

Streszczenie

Przedstawiono aktualny stan badań nad problematyką rozumienia techniki elektronicznej, z wyszczególnieniem znaczenia obrazów dydaktycznych w rozumieniu. Teoretyczne rozważania ukazujące konwencję terminologiczną oraz prezentujące liczne prace z zakresu rozumienia techniki uzupełniono przedstawieniem wyników badań efektywności rozumienia elementów, układów i urządzeń elektronicznych przez uczniów szkoły ogólnokształcącej przy wprowadzeniu różnych technik metodycznych umożliwiających modernizację formy i treści obrazów dydaktycznych.

Introduction

In recent source materials on the theory of general technological education, "understanding" is not only placed on the list of basic criteria for educational contents selection, but it is also given the dimension of a psychological axis of content realization (FRANUS 1982, FURMANEK, 1987, MARSZAŁEK 2001). Understanding viewed as an act of consciousness, a process or cognitive ability lies at the basis of including the taught contents into the individual repertoire of student's behaviors.

In gaining individual (ontogenetic) experience, great importance must be attached to image. Accompanying operative and verbal contents, images are easily digestible, due to their similarity to imaginary patterns, and they also replace, supplement or fix them perfectly in the mind. The significance of image in the teaching activity is also conditioned by the fact that in cognitive processes images are one of the basic ways of presenting the world, which surpasses verbal representation in ontogenesis (cf. DYLAK 1995).

Didactic images are the more important, the higher the degree of abstractness of teaching contents is. We come across such situations – of high abstractness of contents – in the teaching of electronics.

Numerous authors of professional literature on the topic point out to the fact that the process of reaching the understanding of electric and electronic structures is complex, and that it differs substantially from the process of understanding mechanical structures (PUDŁOWSKI 1990, MARSZAŁEK, 1997, FRANUS 2000). The functioning of electronic structures is not accompanied by as numerous external symptoms as is the case of mechanical structures. The flow of current or an electric signal is imperceptible. We can become convinced about its existence only in the few situations when it becomes converted into sound or image (very rarely into temperature or smell).

Also the external structure of elements of electronic systems, apart from some elements such as loudspeakers, a television picture tube, a display or an aerial, does not enrich substantially the observational material. The interior of a device is a "black box" which, after the power supply has been turned on, performs particular functions, most often amounting to the conversion of signal.

Understanding technical structures

Understanding technology has been the subject of several research works. The issues of understanding were transferred from the area of philosophical and psychological considerations to the domain of work psychology and psychology of technical education by FRANUS (1967, 1978, 2000). Referring to SZEWCZUK's study (1960), E. Franus formulated a more detailed classification of various terminological approaches to understanding, and distinguished kinds and levels of understanding hand working tools. SHARMA (1972) chose a slightly different way, establishing child's developmental standards on the basis of a projective test: a drawing of a bicycle. KUDRIAVCEV (1975) presented the results of research on the process of interpretation of a diagrammatic drawing. A further development of the methodology of research on understanding technology is connected with GRACZYK's (1980) work on understanding mechanisms. The author distinguishes between three stages of the process of understanding technical (mechanical) structures: a recognition of the whole structure by recognizing characteristic elements, a precise recognition of components while taking into consideration the recognition of the whole, and specifying the cause-and-effect interrelations vital for the functioning of a structure. Subsequent surveys of cognitive nature whose author was PUDŁOWSKI (1990) are related to an analysis of the students' understanding of electric circuits, while those of MARSZAŁEK (2001) concern understanding electronic structures.

Understanding is considered as an ability to recognize the nature and meaning of a given phenomenon or object. It manifests itself in recognition and explanation: finding correlations between what is given in observations (HURLOCK 1985, MARSZAŁEK 2001).

Understanding electronics

Interpreting technology subjectively, the understanding of electronic technology can be defined as an ability to get to know the nature of electronic devices, systems and elements. Therefore, it manifests itself in identification (the understanding of a name), specifying the general function and auxiliary ones (the understanding of functions), explaining the operation (the understanding of the principle of operation) and specifying characteristic features (the understanding of parameters).

It can be noted that all the specified components of understanding electronic technology, particularly the main one, i.e. the understanding of operation, can exist on various levels: from the lack of understanding (sometimes erroneous understanding), through an incomplete understanding till the thorough one. At the same time, it can be noted that while the lower and middle level can be fairly unambiguously specified, setting the final level, i.e. the "full understanding of the principle of operation", seems to be a disputable question. There can always be asked another question "why?" that will finally remain unanswered. Thus, specifying the degree of the level of understanding electronic technology indispensable for proper functioning in the technical environment was selected as one of the objectives of research conducted by the author in the nineties.

Research results led to the general conclusion: understanding the principle of operation is of a multi-layered, hierarchical character. Understanding the functioning of electronic technology objects by means of a mechanical analogy is conditioned by understanding the operation system and the operation description. The understanding of a mathematical description arises on the basis of understanding band diagrams, which in turn is based on the understanding of area model, the characteristics, the mechanical analogy and the operation system.

The above regularity is accurately illustrated by a graphical model, the so-called pyramid of understanding (Fig. 1).

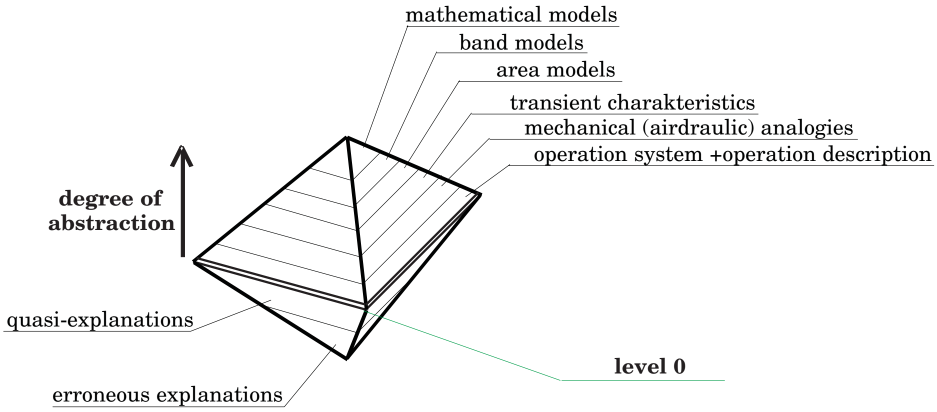


Fig. 1. Levels of understanding electronic technology – a pyramid of understanding (Marszałek 1997)

The above analysis of understanding the principle of operation induces us to draw the following conclusions: the majority of explanations do not substantially penetrate the purely physical principles of the structure of matter and the phenomena which accompany impingements in specific conditions. Persons using characteristics (that is, the external manifestations of functioning) and an area model in understanding the principle of operation exhibit the highest degree of understanding electronic systems and devices. A relatively large number of persons uses quasi-explanations, which in consequence results in their having great difficulties in understanding the operation of systems and devices, the functions as well as the parameters of elements, systems and devices.

Another extremely important aspect of the problem is worth mentioning here. Leading to a high level of understanding is a very complicated long-term process. It requires a significant expenditure of effort, means and time. Thus, it is of certain importance to take this fact into consideration in the principles of educational policy.

In longitudinal research, the existence of sensitive (critical) period of understanding electronic technology was observed. It lasts to 11 or 12 years of age, i.e. the age when the invariants of number, mass and volume are already established. The lack of proper explanation of phenomena in the electronic technology that surrounds the students is connected with an erroneous (according to J. Piaget, magical) record of the image of the world of technology, based, among other, on attributing inanimate objects with features of life – animism or human characteristics – anthropomorphism. It is very difficult to correct evident errors in understanding in the following years, and shortcomings in teaching technology in primary grades are one of the main reasons for commonly observed difficulties in the proper understanding of technology by students of higher grades as well as adults.

Didactic images

A didactic image has been assumed to be a plastic structure made on a plane, including the features of denoted objects and facilitating the accomplishment of assumed didactic aims (FLEMING 1965). A multitude of images as well as their various functions determine the necessity for grouping them in larger wholes.

Assuming manufacturing technique to be the classification factor, didactic images can be classified as images made with: a pencil, paint, a camera (photographs), a computer, etc.

As regards the degree of mapping of object features, images can be divided into two groups (JAGODZIŃSKA 1991):

- images similar to denoted objects, elsewhere called representations; in this group there appear direct images (similar to denoted objects) and indirect ones (similar to the view of the situation in which the denoted objects occur);
- images similar to objects other than the denoted ones, called symbols, which can appear as abstract images (similar to abstract shapes) and metaphoric ones (similar to the appearance of objects associated with the denoted object).

Taking into consideration the degree of mapping of movement of the presented objects, images can be divided into two groups:

- static images, presenting objects at a given time; and
- dynamic images (elsewhere called cinematic images, animations), showing objects in motion.

In relation to verbal information, graphic information can be present in three relations: redundancy, complement or distinctness (JAGODZIŃSKA 1991).

Facilitating the implementation of didactic aims amounts to the possibility of presenting only typical features in the drawing and passing over the details, for a proper selection of important elements and setting them apart in a proper graphical form dependent on the purpose and degree of the addressee's preparation constitutes a graphical, didactically correct synthesis of the object, which is clearer and easier to perceive than the natural object or its exact reflection (ZILBERSZTEJN 1957, WINKLEWSKI 1962 quoted in SOKOŁOWSKI 1978).

Didactic images in teaching electronics

In teaching electronics, didactic images are widely used:

– symbolic images – in the form of symbols, (structural) schematic diagrams and block diagrams;
– direct images (representations) – in the form of analog models, area models, assembly diagrams, representations of devices, phenomena of the micro- and macro-world, assembly drawings and the course of assembly and disassembly activities.

Symbols of electronic elements, schematic diagrams composed mostly of geometrical figures, reflect the appearance of elements to which they are related (the denotatum) to a very small or no extent. In a minimal, but slightly greater degree, graphical signs illustrate the principle of operation of an element. According to FRANUS (1978), an elementary reading of a symbolic drawing differs from a reading of a demonstrative one with respect to the course. While reading a demonstrative drawing proceeds through imagining the object and then naming (conceptualizing) it, a symbolic drawing is read by naming the object and then, by imagining it.

As can be noted, the presented general scheme of decoding a symbolic drawing can be slightly modified depending on the experience of the reader (the level of formation of the ability to read), a type of activity (the purpose of reading) and own predispositions (MARSZAŁEK 2001).

An inexperienced person who sees e.g. a symbol of a transistor with a type description decodes it by conceptualization and then, by imagining the object, not paying attention to the description. Having a greater experience, the person imagines the object in a more detailed way, taking into consideration the specificity of description, the type (Fig. 2).

While conducting diagnostic, constructor's activity, as one becomes more and more skilled, reading a symbolic drawing proceeds from the scheme: symbolic drawing – conceptualization – appearance of the object – functional model, to the scheme which is most often binary: symbolic drawing – functional model. The process of reading can be illustrated by LECH's (1960) model of thinking which consists of three levels: the concrete, imaginary schemata and conceptual structures (KOŁKOWSKI, KWIATKOWSKI, KWIATKOWSKI 2001).

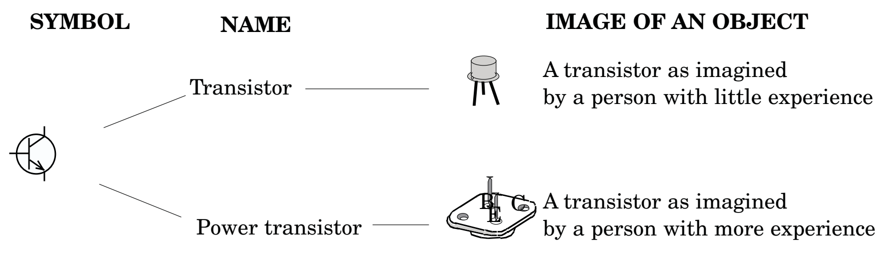
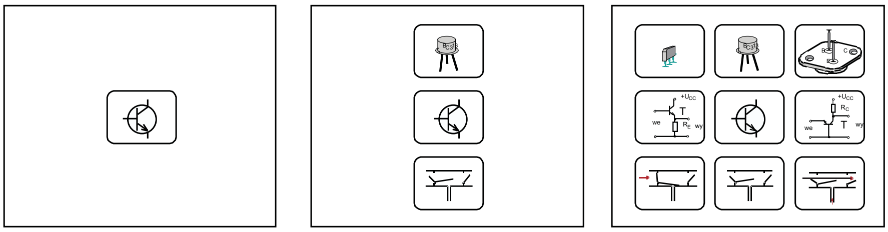


Fig. 2. Representations of an object when a symbolic drawing is read by persons with a different experience

Looking at a symbol of a transistor, an experienced electronics engineer "sees" lines of force of an alternating magnetic field generated by the primary winding, which include the secondary winding, inducing electromotive force in it. He/she estimates the value of induced electromotive force depending on the value of voltage applied to the primary winding, the ratio and the alternations of current in time. Looking at two parallel lines (the symbol of capacitor), he/she sees electric charges gathering on plates, which accumulate to the degree/level which is the higher, the higher the supply voltage and the smaller the changes of current in time. Looking at the symbol of bipolar transistor, he/she notices high collector current controlled by the base current. Sometimes, e.g. during a quick analysis, these schemes assume a simplified resistance shape, allowing for the establishment of values of voltage drops on particular elements of the system. For example, for constant current, a capacitor is seen as a break in the circuit, for slowly changing electric currents – as a resistor, and for fast changing current pulses – as a conductor. Only in this particular case we cannot agree that a symbol is transparent to the image of the object of perception (FRANUS 1978, JAGODZIŃSKA 1991).

The course of decoding symbolic images depends also on individual predispositions of a reader, and most of all, on the development of imagination. ALTSHULLER (1986) equals its basic feature, i.e. creating mental images, to the number of mental screens produced at the same time. When looking at a symbol or talking about something, a person of little creative predisposition creates one imaginary model – a mental screen. A more creative person creates three, while one of a significant potential – nine. For example, looking at a symbol of a transistor, an uncreative person maps only the symbol in his/her mind. For a person with an average creative potential, there emerge three screens: one with a symbol, the second one – with the appearance of transistor and the third one – with a model of mechanical analogies. A person whose creative potential is significant can create, apart from the aforementioned ones, images of various types of transistors, various operation systems, substitute functional models for various signals (Fig. 3).



an uncreative person | a person of an average creative potential | a person of a hight creative potential

Fig. 3. "Mental screens" with the symbol of transistor as perceived by people with different creative potentials (ALTSHULLER 1986)

The quoted author stresses the fact that "activating" nine mental screens does not constitute the limit of man's mental capacity.

Perceiving cause and effect relationships consists in the translation of symbols into a conceptual language, and in mental transformation of static images (mechanical analogy models, area models) into dynamic phenomena (KUDRIAWCEW 1975). When students read schematic diagrams, there appear typical errors which are mainly caused by the following:

– discrepancies between perceived symbols and imaginary schemata,
– difficulties in imagining process dynamics on the basis of a static diagram,
– lack of capability to identify the main elements on whose basis a functional block is formed,
– incompetence in establishing relationships between elements,
– difficulties in separating vital information from unimportant one (FRANUS 1978).

Eliminating the mentioned errors or leveling the discrepancies: particularly the teacher "annoying" in didactic activity, has been the subject of methodological research conducted by the author since the beginning of the nineties. In the research carried out in the years 1990–1994, the relationship between the introduction of modified teaching contents (modified didactic images were also included in the experimental factor) and the effectiveness of teaching technology in grammar schools was established. In the following years there took place an empirical verification of four methodological techniques, allowing for the creation of correct dynamic schemata in the student's mind, which were to increase significantly the understanding of electronic technology, namely:

– an analysis of static diagrams constructed on the basis of mechanical analogy,
– an analysis of dynamic diagrams constructed on the basis of mechanical analogy,
– dynamization of tabular static diagrams,
– an analysis of dynamic diagrams.

The first technique consists in drawing mechanical schemes which reflect elements and connections present in an electronic system. Drawings of mechanical elements are representations or metaphoric drawings, and the process of decoding such a drawing is much simpler than that of decoding a schematic (symbolic, abstract) drawing (ŁOMOW 1966).

Mechanical analogies can assume the form of dynamic models, in which it is easy to observe the flow of "current", the opening and closing of circuit and the flow limitation. Dynamic models can assume a flat form or a spatial one. Examples of the flat form are phasegrams and dynamic computer presentations, while those of the spatial one are material models of real objects.

Dynamizing tabular static diagrams consists in "enlivening" a schematic diagram. This can be achieved by applying a number of procedures:
– presenting the ways of connection and the general function of elements while drawing the diagram,
– drawing the diagrams stage by stage, beginning with basic diagrams and extending them by adding new elements,
– marking the flow of electric current in the limbs of circuit and resistance voltage drops,
– symbolic marking of changes (increase, reduction) of voltages, currents and resistance of a cause-and-effect nature,
– drawing diagrams depicting system parameter changes in time,
– identifying mathematical regularities.

Dynamic images contribute to a better understanding, particularly of the systems in which there exists a significant concentration of phenomena or elements. The function of dynamic images is performed perfectly by computer images (animations), by employing a cyclical presentation of static images and complementing them with a verbal description and tabular drawing. This fact motivated the construction of computer programs (by the author or under the author's didactic supervision) presenting the operation of basic elements, systems and devices of electronic technology.

In the research, four indicators of understanding electronics were adopted. They had been specified by the ratio of the arithmetic mean of results obtained in the experimental group (consisting of 65 students aged 15, into which the experimental factor was introduced) and in the control group (62 students):
– indicator of understanding the name (identification of electronic elements, systems and devices),
– indicator of understanding functions (specifying the general function and auxiliary functions of electronic elements, systems and devices),
– indicator of understanding the operation (the explanation of operation of electronic elements, systems and devices),
– indicator of understanding the parameters (determining the quantities and units which are characteristic for electronic elements, systems and devices).

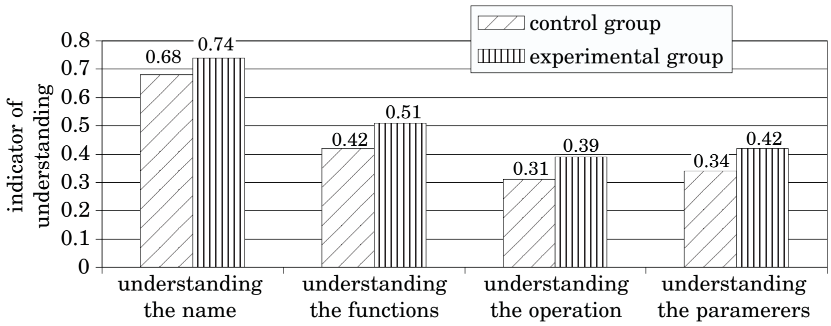


Fig. 4. The values of quotients of understanding electronic technology

The "Elektor 2a" test – a modified version of the "Elektor 2" test served as the research tool (MARSZAŁEK 2001).

The results unambiguously confirm the adopted research hypothesis: an introduction of modified graphic methodological techniques will increase the degree of understanding electronic technology. An analysis of results shows that in all the dimensions of understanding there is a statistically significant difference between the results achieved in the experimental group and those in the control group on a significance level of $\alpha = 0.05$ and $\alpha = 0.01$, the exception is understanding the name. The greatest divergence between the results of groups appears in the domain of understanding the principle of operation (understanding effectiveness quotient $w_{rz} = 1.29$), then, understanding the parameters ($w_{rp} = 1.24$) and understanding the functions ($w_{rf} = 1.21$).

Conclusions

Introducing graphical contents in teaching electronics, as numerous research results show, has a significant influence upon the understanding of elements, systems and devices, and consequently - upon the effectiveness of teaching. Improving didactic images, including, among other, the use of computer technology for creating dynamic images and dynamizing tabular images, should be strictly connected with an analysis and a possibility of activating the ability to understand, using the specificity of impacts on particular stages of student's development. Works on the modernization of graphical contents and their practical verification in teaching electronics to students majoring in technology and computer science education are currently being carried out at the Department of Electronics Teaching, Institute of Technology, University of Rzeszów.

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