© University Press 2023
ISSN 2719-6550
ISSN 2719-7417 online

"Journal of Education, Technology and Computer Science"
No. 4(34)/2023
www.eti.ur.edu.pl

Received: 1.09.2023
Accepted for printing: 15.12.23
Published: 29.12.2023
License: CC BY-SA 4.0
DOI: 10.15584/jetacomps.2023.4.6

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Didactics of Electrical Engineering and Its Components in the Context of Digitalization of Education

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Abstract

Didactics is defined as the theory of education. It deals with the specific forms, procedures and goals of teaching that a teacher implements with his/her students. As such, it is an integral part of pedagogy. Since the forms, procedures and objectives of teaching vary in their specificity for the different fields, disciplines and subjects of education, this specificity is reflected in the disciplinary or subject didactics. The latter thus deal with the processes of teaching and learning with regard to subject-specificity and specificity. The article is thematically devoted to the area of subject or subject didactics, specifically didactics of electrical engineering, which is of particular importance for vocational technical education, as it forms a key part of it both in practice and in the preparation of teachers of such disciplines. The article also presents some of the results of the author's research from recent years, which focuses specifically on the areas of modern technologies and their impact on the teaching process, especially in electrical engineering-oriented teaching subjects; tools for developing technical but also digital literacy are presented.

Keywords: technical education, electrical engineering, subject didactics, virtual education, studies

Concept of didactics of electrical engineering

Subject and subject didactics together with general didactics belong to pedagogical disciplines that describe and clarify the processes of teaching and learning. General didactics establishes the general laws of teaching. If we focus general didactics on the teaching of vocational subjects, we get from the general position to the specific position, i.e. to the subject didactics (Honzíková, Bajtoš, 2004).

Subject and subject didactics deal with the processes of teaching and learning with regard to their field affiliation and specificity. These are disciplines situated between a certain technical, artistic, or other field and the sciences of education and training. The general term field/subject didactics is often replaced by a term expressing the didactics of a particular field/subject (e.g. didactics of mathematics, didactics of electrical engineering, etc.).

The term field refers to a professional area within which specific problems are solved. The relationship between didactics and the field is dynamic and can take various forms, but it is always necessary to balance the conditions of the pupil's learning and the quality of the subject. Subject didactics is therefore a science mediating the field towards pupils/students [1] with the help of knowledge of pedagogy and general didactics, pedagogical and developmental psychology and other disciplines. Subject didactics is therefore interdisciplinary (Janík, 2009; Ouroda, Švec, 2000).

Subject didactics deal with problems of teaching in specific subjects and are usually understood as their methodologies (Průcha, Walterová, Mareš, 2013). Subject didactics have a direct link to the relevant subjects – subject didactics are profiled as relatively autonomous scientific disciplines, the subject of which is "the entire communication process in the relevant field and the corresponding component of education" (Brockmeyerová-Fenclová, Čapek, Kotásek, 2000).

Didactics of electrical engineering is the theory and practice of teaching and learning electrical engineering subjects in relation to education and formation of knowledge, skills, competencies, attitudes and other dispositions, it is a summary of didactics of individual electrotechnical subjects, but it is not the sum of didactics.

Didactics of electrical engineering can be divided into parts:

(a) the general and

(b) special.

The general part discusses:

- subject of didactics of electrical engineering,
- the history of teaching electrical engineering, and
- educational importance of electrical engineering.

A special section discusses:

- the content of the apprenticeship/field of electrical engineering, and
- means by which the main educational objectives of the subject/field of electrical engineering can be met.

[1] Note: not all content in the field is conveyed, but those that appear to be useful from the point of view of teaching and learning, i.e. contribute to the development of knowledge, skills, competences, attitudes and other dispositions of pupils/students at a certain level and type of school (see didactic transformation) are selected.

If we characterize didactics of electrical engineering subjects as a science, then we understand didactics of electrical engineering as an interdisciplinary, independent borderline scientific discipline that didactically processes the knowledge of electrical engineering and integrates it with the knowledge of social sciences into a didactic system of electrical engineering subjects.

The task of the didactics of electrical engineering is to turn the scientific field of electrical engineering into a teaching subject. The tasks of the didactics of electrical engineering can be seen (Serafín, 2023):

– in the meaning of the electrotechnical subject and its position in the school educational program;

– in the objectives of the electrotechnical subject and its curriculum (concept, selection, scope, arrangement, cross-curricular links, methods, etc.);

– in the teaching process, its laws, didactic principles and means;

– in the conditions of teaching, the personality of the teacher vs. the student;

– in the history of the subject;

– in relation to other scientific disciplines.

The aim of teaching electrical engineering is understood as intended changes in learning and development of the pupil, which should be achieved by teaching electrical engineering. The intended changes concern both changes in knowledge, skills, and habits, as well as changes in personal value orientations and the social development of the pupil. It is therefore an anticipated, expected learning outcome, towards which pupils aim in cooperation with the teacher (Serafín, 2023).

Online electrical engineering education – options and tools

Computer and recently computer and digital literacy is now considered one of the basic prerequisites for human education. The goals of technology-oriented literacy and work with it should lead people to cope with the increasing range of information and allow him to orient himself in them. Primary, secondary and higher education institutions already implement these competences (in various forms, forms and scopes) in their graduates, and these competences are therefore part of the so-called learning outcomes. Multimedia technologies, which are associated with them with the development of methods and forms of learning, have thus become part of the way of organizing studies within all educational levels. It is generally accepted that in the process of pedagogical interaction and communication, technology is increasingly becoming an intermediary between teacher and learner, but it should never replace interpersonal relationships and impoverish social ties (Hrušková, 2009).

At the turn of the millennium, e-learning was considered the key educational form of the 21st century. This euphoria was replaced by the realization that e-learning cannot replace traditional educational forms, that e-learning can only function as a support for the teaching process. If we connect face-to-face teaching with e-learning, we are talking about blended learning. According to Zounek (2009), it is the integration of electronic resources and tools into teaching with the aim of fully exploiting the potential of ICT in conjunction with proven methods and means of traditional, face-to-face teaching. The basic models of blended learning according to Kopecký (2006) can be divided into three categories:

1. Skill-driven learning – combines personalised learning with teacher support.

2. Education focused on the development of attitudes or approaches (attitude--driven learning) – works here with selected events and mass media, with the help of which the behavior of the learner is influenced.

3. Education focused on the development of competencies (competency--driven learning) - a combination of several methods that can influence the development of the learner's competences.

E-learning, especially in the case of technical fields, brings new ways of working with the acquisition of information and experience while changing (to some extent) the learning process. A number of methods used by e-learning in practice are taken from classic face-to-face teaching. The basic difference is mainly in the change in the approach to education, from an instructive to a constructive approach (Kopecký, 2006), where the direct teaching method is replaced by the principle of constructing knowledge in partial steps using the pupil's own creative activity.

Modelling and simulation in electrical engineering

It is clear and understandable that today's pupils are not only self-evident users of computer-related technologies, but often have programming knowledge and skills at a relatively high level. However, it is always up to the teacher whether they will become mere "users" of applications in their lessons, where students will be able to retrieve and analyze results very quickly, but will not understand much about what they are doing, or whether they will start using these tools to solve practical problems. Although the first case is important for practical knowledge, in the second case it is a basis in which students cannot do without knowledge of the theory as well as the principles of analysis methods implemented in software circuit simulators (Biolek, 1999).

Today, simulation programs open up a huge field of possibilities for analysis and simulation of processes in complex electronic circuits. Thanks to the power of contemporary computers and the result of historical development that began in the fifties of the last century, programs designed for simulation of analog and digital circuits are now the standard of virtual laboratory instruments. The standard of analog simulation is SPICE, while in digital simulation there are several software tools, while simulators with the attribute “Mixed-Mode” have the ability to simulate circuits at both analog and logic levels. The SPICE (Simulation Program with Integrated Circuits Emphasis) is a program that originated in 1971 (Shepherd, 1996) at the University of California. The author is Larry Nagel. It is a developmentally higher version of the CANCER program (Computer Analysis of Nonlinear Circuits Excluding Radiation). The modelling principle is then shown in the following Figure 1.

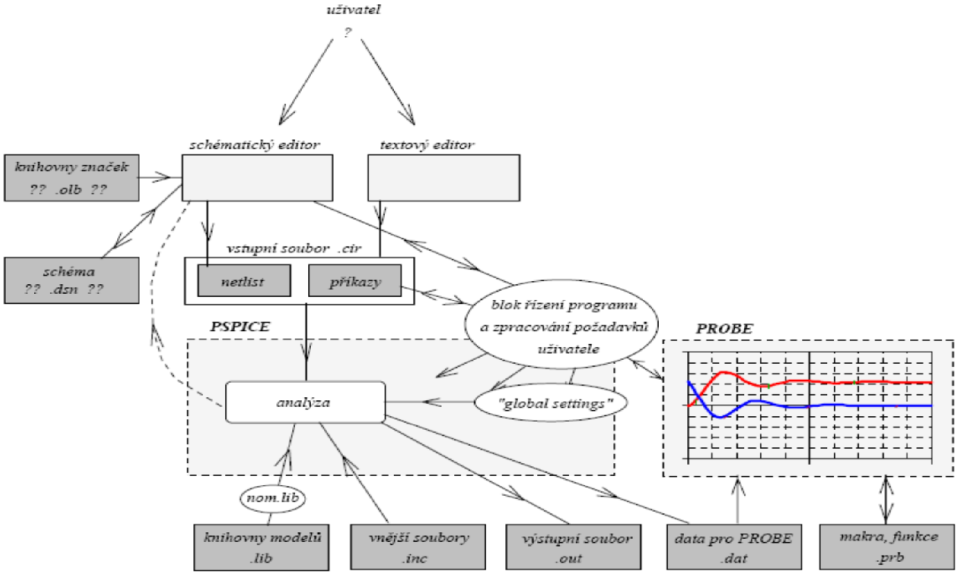

Figure 1. Principle of modelling

Source: Biolek (2005).

Analysis of electrical circuits can be characterized as a specific procedure from the circuit model to obtaining the result. Currently, existing methods of analysis can be divided into non-algorithmic, or heuristic, and algorithmic (Biolek, 1994). Among the first can be included procedures that the solver chooses on the basis of his and previous experience, it is therefore o constructivist approach. The algorithmic method, on the other hand, defines the exact procedure – the algorithm, i.e. the solution of a circuit using the nodal voltage method. Each of these methods fulfills its function in the solution: non-algorithmic methods force the solver to creative technical thinking; algorithmic then provides a tool for solution.

Modeling can be defined as the process of describing reality by limited means, where the result is a model of the original object. Modelling is derived from the Latin concept of mode, modulus (measure, pattern, manner). In other words, the model can be understood as a simplification of a certain real or abstract object. In other words, it is a bridge between theory and objective reality (Seraphin, 2018). The models that are created in the simulation can be both simple and complex. Models that are more complex bring a better imitation of a real object; however, they bring with them the problem of the complexity of creating such a model. Analysis is then a one-time activity, when by examining the model, we try to find out a certain property of the original and, last but not least, simulation is an activity where by analyzing the model we try to obtain the most faithful picture of the behavior of the original under precisely defined conditions.

Programs for solving circuits are sometimes divided into analyzing (analyzers) and simulation (simulators). However, the difference between them is usually not sharp, because they are to a greater or lesser extent able to realize a range of different types of analyses in both categories, using even complex models embedded in feature libraries.

Model analysis has its goals, inputs and outputs, method, form and means of implementation. The form of the analysis is then determined primarily by the means of its implementation, i.e. a computer with the relevant software, while the form of internal analysis procedures is hidden from the user and depends on the numerical algorithms used and their programming by the software creators. In addition to computational goals, the analysis may also have other goals, for example, the teacher can assign pedagogical goals (practicing a specific method of analysis, understanding a certain process in the district, etc.).

The phenomenon of simulation programs for electrical engineering or electronics does not distinguish boundaries between school levels. However, it depends on the use of these programs in schools, which can also be counterproductive (Biolek, 1999a). Today, computer simulation and circuit analysis are mainly carried out in the following areas (Biolek, 1999b):

1. Use of special software – typical representatives are programs such as TINA, MicroCap, Multisim, etc.).

2. Use of universal programs for mathematical-scientific calculations such as MATLAB, MAPLE, etc.

Methods of analysis of electrical circuits should not only serve as a tool for solution, but the teacher can also use them for explanatory purposes. The approach to teaching in this concept therefore has many different features from classical laboratory teaching and combines different methods and procedures. Levert and Pierre (2000) offer a methodology – a broadly conceived concept of virtual lab modeling and the use of simulation models that should work in different configurations and on different platforms (Michael, 2001; Musil, Dobrovolný, Stříbrný, 1997).

Closely related to the model, modeling is the concept of simulation, which is actually the imitation of reality, real state or process, using a model that imitates them (Serafin, 2023). The very act of simulation in general terms implies the display of some key properties or behaviors of selected systems (Hertel, 2002). Using Simulations to Promote Learning in Higher Education. Sterling, Virginia: Stylus). According to Serafín (2023), the simulation is a model that is designed to monitor dynamic processes using physical knowledge that is mathematically expressed.

Simulation of virtual electrotechnical kits can be entered in two ways. The first way is using a text editor, which is usually part of simulation programs. The second way is a schematic editor. The specific scheme is then shown in the following figure, where an example of the scheme is shown.

Of course, both of these ways weigh in with certain advantages and disadvantages. The advantage of the schematic editor is the clarity of the model. However, the controls vary depending on different programs. Text editors are standardized, but knowledge of programming languages is required. The simulator user then requires the process from input to result to be fast, user-friendly. This depends on the quality of the mathematical algorithm used by the simulator, on the amount of analysis available to a particular user, on the assortment of analysis modes, on the programmers, whether they tried to ensure the "user-friendly" assumption of the program (Serafín, 2023). The simulator predicts the behavior of the circuit, as in reality. Models that have certain properties replace specific components that would be used in the circuit. They are thus representatives of real components.

When simulating electrical circuits, the elements of the electrical circuit are described by physical parameters and stored in so-called libraries. These are part of the simulation program. Models can be defined by your own or modified.

Demonstration of electrical circuit simulation and its verification

For an example of a practical demonstration of electrical circuit simulation using virtual tools and its verification in practice, the Tinkercad virtual environment was chosen. A virtual multimeter was used to measure quantities. Subsequently, the virtual circuits were implemented in a real physical environment using the Arduino kit.

Measurement of LED circuit – off, on

The first example is the measurement of the voltage drop on the LED and the current passing through the diode, which is limited by the series resistance (Figure 2–3). For clarity, the voltage value on the Arduino output pin is displayed. The voltage drop on the LED is 2.00 V. The current through the diode is 11.1 mA. The voltage on the Arduino pin is 4.44 V.

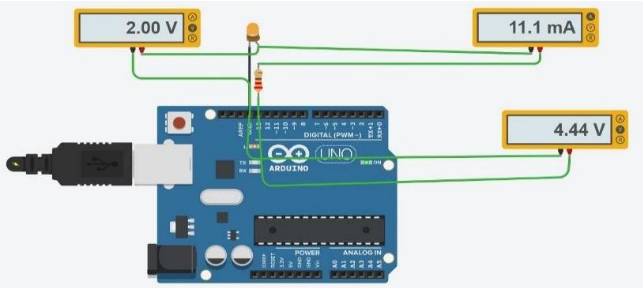

Figure 2. Simulation of led wiring (Tinkercad)

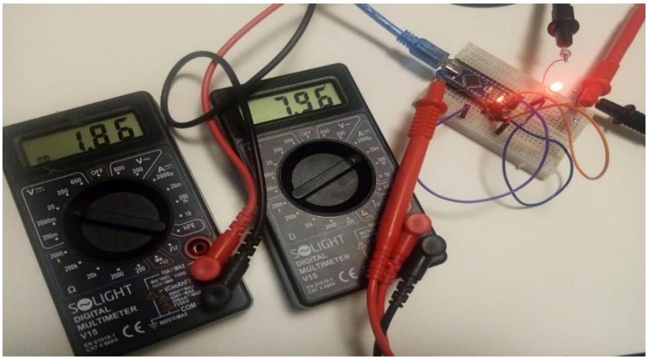

Figure 3. Simulation of led wiring

Measurement of led-PWM excitation circuit – stepless brightness control

As a second example, the brightness of the LED is changed by PWM modulation. The program continuously increases the current of the LED in 255 steps. In the figures, we can see differently changing values that capture the progress of the code. The quantities are directly proportional to the brightness of the diode (Figure 4–5).

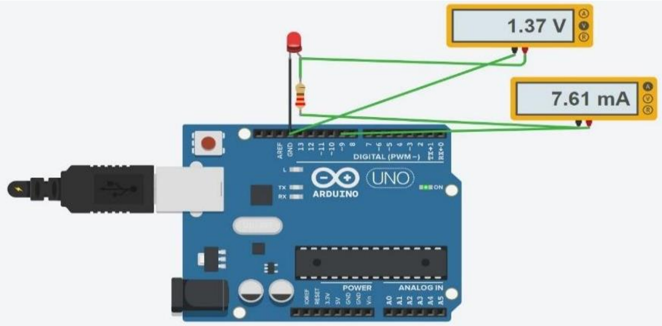

Figure 4. Simulation of led wiring with PWM excitation, continuous brightness control of led (Tinkercad)

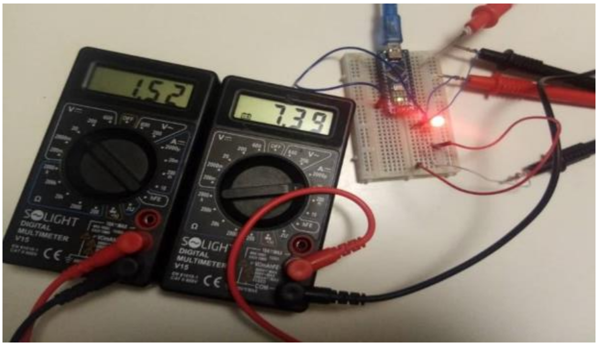

Figure 5. Simulation of LED wiring with PWM excitation, continuous LED brightness control

Application of didactic principles in vocational electrical education – influence of digital technologies

According to Hawkridge (1990), the potential of digital technologies in education can be seen as an essential tool for transforming schools into the digital age and transforming styles and the learning process. The world of digital technologies surrounds us. Digital literacy is becoming as important as literacy or numeracy. Knowledge of technology and the ability to use it to effectively solve problems naturally becomes an important part of education. Combining industry knowledge with relevant information and communication technology knowledge as well as relevant skills is key. It is a complex process in a multicultural environment requiring specific approaches that go beyond the limited boundaries of traditional teaching from the educational point of view. An approach that combines behaviorism, cognitivism and constructivism is *connectivism*, or the theory of learning in the age of information communication technologies (Siemens, 2005). Connectivism taking into account the fact that the one who studies constructs a system of knowledge in the conditions of his social environment, which takes place with the support of information communication technologies and tools in the environment of a computer network. As a result, it goes beyond the individual (Klement, Dostal, Kubrický, Bártek, 2017). Of course, the role of the teacher also changes, moving from an authoritative source of knowledge to the position of helper, advisor and inspirer, supporting students in their own education. A key aspect here is that the volume of information that learners encounter and work with is thus too large to be contained by learning or experience, and at the same time it changes too quickly over time (Klement et al., 2017).

Digital literacy and interactive education in teacher training

In the contemporary concept, a person who is able to use digital technologies for their personal development and civic activities is digitally literate. The very concept of digital literacy is inextricably linked to the understanding of digital competences as a set of knowledge, skills and attitudes, including relevant competences, strategies and values. These are, of course, sets of competencies necessary to identify, understand, interpret, create, communicate and safely use digital technologies. Digital literacy can thus be seen as the result of formal and non-formal education and informal learning, within which relevant digital competences can be acquired, and thus, according to Martin (2008), digital literacy includes the ability to successfully carry out digital activities, which may include work, learning, leisure and other aspects of everyday life.

Digital literacy and thus digital competence are inextricably linked with technical competence. Interactive and multimedia teaching is a means that allows you to bring creative activities with game elements into education and thus create a more attractive, motivating learning environment increasing the effectiveness of education. However, emphasis needs to be placed on the fundamental difference between activities such as play and guided learning. In the case of use as a teaching aid, the term activity with game aspects can be used (Čáp, Mareš, 2001). The contemporary concept is thus close to the virtual educational environment with elements of activating games. Virtual reality creating the illusion of the real world in conjunction with interactivity can realize teaching in real time according to the user's wishes. Warthová (2016) points out the possibilities of using virtual reality in teaching, where teachers often have a problem to sufficiently engage pupils, and so a solution is offered in the form of virtual reality. According to a study by Chi-Yin (2011), pupils working with augmented or virtual reality understood the subject matter much better than pupils using other educational aids (textbooks, educational software and videos). Augmented or virtual reality helps to better understand the material, is more illustrative and easier to remember.

As part of the research, we asked student teachers about their abilities and digital literacy skills. This area can be based on different evaluation models – such as the European Framework for Digital Competences for Teachers (DigCompEdu), which characterizes 22 competences classified into 6 levels. Jeřábek et al. (2018) divides these competencies into 3 levels – basic, intermediate and advanced (Table 1).

Table 1. Model of digital competence levels for education

Level	Complexity of tasks	Independence	Cognitive area
Basic level	Simple tasks	under the guidance or without direct support	remember
Intermediate level	well-defined or routine tasks and simple problems	independently or according to your own needs	understand, apply
Advanced level	Tasks and problems of various kinds	leading others, the ability to adapt to others in the context of the complexity of the task	analyze, evaluate, create

Source: https://pages.pedf.cuni.cz/gramotnost/files/2019/01/01_Jerabek.pdf.

The research was built on a quantitative research design, the aim of which was to recognize the experience of educators regarding the mastery of digital technologies in teaching and the relationship to technology in general. The questionnaire measurement was carried out on 257 respondents, of which 125 were men and 132 women.

The research did not find that the gender of future teachers affects their abilities in the use of digital technologies, and was subsequently asked about the subjective level of knowledge of computer science in the context of previous competencies that respondents acquired through previous studies at primary and secondary schools. The word "subjective" is used here deliberately, as the level of knowledge and skills is assessed by the respondents themselves, which can lead to distortions in the perception of the actual level. The results showed the dominance of work with text, graphics, the Internet and the relevant technological devices. Respondents considered these areas of competence to be quite optimal. On the contrary, there was a very low level in programming, robotics, web creation and work with databases. These are the areas that need to be emphasized in teacher training, across subject approbations. This result can be seen as a logical consequence of the obsolescence of educational processes not only in the context of higher education for teachers, but also as a consequence of the decline in lifelong learning in this area. In 2023, a survey of 1267 Ipsos enterprises was conducted for the Chamber of Commerce, the Confederation of Industry and Transport and the Confederation of Employers' and Entrepreneurs' Associations[2], which concluded that development is only possible if we invest in technical infrastructure, high-capacity data networks, modern technologies based on automation and especially robotization, where the use of robots and artificial intelligence is essential. However, this cannot be done without people who have the appropriate professional competences, which are provided by education, and this does not produce graduates in the Czech Republic who will have skills in line with the demand in business.

Conclusion

The paper brings views on approaches to teaching in the preparation of future teachers of technically oriented disciplines, specifically electrical engineering. Although the goal is so narrow, its scope is much broader and more general, because it actually affects every teacher without depending on his qualifications. Education has always reacted to any changes with a long delay – given the nature of the curriculum-based implementation, which has been valid for many years. Teachers are able to suppress this handicap of education only by

[2] https://www.seznamzpravy.cz/clanek/ekonomika-firmy-jsme-skanzen-mirime-ke-kolapsu-ceske--firmy-vystavily-statu-vysvedceni-236237.

their own work, their knowledge and skills, orientation in new conditions, trends and possibilities, but they do not always have optimal conditions for this on the part of school management, but also on the part of teachers themselves, their self-education and personal development.

Part of the society is the education of its members so that the society can further develop, and this is what didactics is for. Without understanding what electric current is, for example, a person would never be able to discover a transistor, an integrated circuit, a CCD, and more. Only teachers have the opportunity to teach future generations of Nobel Prize winners, future generations of personalities who will develop new technologies.

References

Biolek, D. (1994). *Výuka obecných metod analýzy lineárních obvodů*. STO-5, VA Brno. Retrieved from: http://www.vabo.cz/Stranky/biolek/veda/articles/STO5_2.pdf (13.12.2022).

Biolek, D. (1999a). *Respektování didaktických principů při využívání počítačových programů ve výuce elektrických obvodů*. Retrieved from: http://www.elektrorevue.cz/clanky/99008/index.htm (13.12.2022).

Biolek, D. (1999b). *Využití programů pro symbolickou a semisymbolickou analýzu elektrických obvodů ve výucei výzkumu*. Retrieved from: http://www.elektrorevue.cz/clanky/99012/index.htm (13.12.2022).

Biolek, D. (2005). *Modelování a simulace v mikroelektronice*. Brno: VUT.

Brockmeyerová-Fenclová, J., Čapek, V., Kotásek, J. (2000). Oborové didaktiky jako samostatné vědecké disciplíny. *Pedagogika*, *50*(1), 23–37.

Čáp, J., Mareš, J. (2007). *Psychologie pro učitele*. Praha: Portál.

Chi-Yin Y., S., Yaoyuneyong, G., Johnson, E. (2011). Augmented Reality: An Overview and Five Directions for AR in Education. *AQUILA*, *4*(1).

Hawkridge, D. (1990). Who needs computers in school, and why? *Computers & Education*, *15*(1–3), 1–6.

Hertel, J.P. (2002). *Using Simulations to Promote Learning in Higher Education*. Sterling, Virginia: Stylus.

Hrušková, L. (2009). Online výuka jako komplexní výuková metoda. *AUSPICIA*, *6*(3).

Janík, T. (2009). *Didaktické znalosti obsahu a jejich význam pro oborové didaktiky, tvorbu kurikula a učitelské vzdělávání*. Brno: Paido, Pedagogickývýzkum v teorii a praxi.

Jeřábek, T., Rambousek, V., Vaňková, P. (2018). *Digitální gramotnost v kontextu současného vzdělávání*. Praha: Univerzita Karlova, Pedagogická fakulta.

Klement, M., Dostál, J., Kubrický, J., Bártek, K. (2017). *ICT nástroje a učitelé: adorace, čirezistence?* Olomouc: Univerzita Palackého v Olomouci.

Kopecký, K. (2006). *E-learning (nejen) pro pedagogy*. Olomouc: HANEX.

Levert, Ch., Pierre, S. (2000). Towards a Design Methodology for Distributed Virtual Laboratories. In: J. Bourdeau, R. Heller, (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2000* (pp. 592–597). Montreal, Canada: Association for the Advancement of Computing in Education (AACE).

Martin, A. (2008). Digital Literacy and the “Digital Society”. In: C. Lankshear, M. Knobel (Eds.), *Digital Literacies: Concepts, Policies, and Practices* (pp. 151–176). New York: Peter Lang.

Michael, Y.K. (2001). The Effect of a Computer Simulation Activity versus a Hands-on Activity on Product Creativity in Technology Education. *Journal of Technology Education*, *13*(1).

Musil, V., Dobrovolný, P., Stříbrný, V. (1997). *Modelování a simulace: program PSpice*. Brno: PC-DIR. Učební texty vysokých škol.

Ouroda, S., Švec, V. (2000). *Oborová didaktika*. Brno: Mendelova zemědělská a lesnická univerzita.

Průcha, J., Walterová, E., Mareš, J. (2013). *Pedagogický slovník*. Praha: Portál.

Serafín, Č. (2018). *Illustrative electrical engineering in the primary school curriculum*. Olomouc: Univerzita Palackého v Olomouci.

Serafín, Č. (2023). *Didaktika elektrotechniky: Rozvíjení kompetencí k řešení problémů.* Olomouc: Univerzita Palackého v Olomouci.

Shepherd, P. (1996). *Integrated Circuits*. Bloomsbury Publishing.

Siemens, G. (2005). Connectivism: A Learning Theory for the Digital Age. *International Journal of Instructional Technology and Distance Learning*, *2*(1).

Warthová, V. (2016). *Rozšířená realita ve školství*. Retrieved from: https://spomocnik.rvp.cz/clanek/17151/ROZSIRENA-REALITA-VE-SKOLSTVI.html (13.12.2022).

Zounek, J. (2009). *E-learning – jedna z podobučení v moderní společnosti.* Brno: Masarykova univerzita.