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Pedagogical Diplomacy II

Electrical Engineering and its Aspects in the Modern Concept of Technical Education

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Abstract

This paper focuses on some aspects in the concept of teaching electrical engineering in technical education. It is presented the issues of possible approaches and tools allowing to implement the teaching of electrical engineering in a demonstrative and entertaining way using contemporary means based on digital technologies. In this framework, the possibilities of motivating students are also presented and some findings from selected scientific papers, domestic and foreign research are also summarized.

The introductory part presents the issues related to the definition of subject or subject didactics of electrical engineering as a prerequisite for successful teaching by teachers. The next part is devoted to a research investigation focused on the application of new approaches to teaching electrical engineering in school practice, the possibility of linking virtual or augmented reality in a demonstrative approach to teaching, the use of online applications to solve electrical engineering problems and thus linking the practical form of electrical engineering with the theory presented in the classroom with the support of digital technologies.

The conclusion then summarizes the possibilities associated with the teaching of electrical engineering and the search for new paths that are common to both students preparing for the teaching profession and the students who will one day be guided by these teachers through the secrets of electrical engineering as one of the most important fields of human activity.

Keywords: Educational research, Subject didactics, Educational process, Teaching management, Electrical engineering, Digitalization, Virtual reality

1 Introduction

The lightning that crosses the sky during a thunderstorm is one of the most visible manifestations of electricity. In almost all other cases, electricity is invisible, yet it serves us tirelessly. Electricity powers machines, controls instruments, and provides light and heat. The signals that make telephones, radios, televisions and computers, are also of electrical

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origin. However, how do we bring this world closer to people who encounter the manifestations of electricity on a daily basis but know little about its nature? How to explain these phenomena? Dry theory, which is most often encountered in physics textbooks and electrical engineering publications (Mayer, 1981); (Cook, 2004), usually does not tell us much. However, what about practically "touching" electricity, testing the theory in a different, more fun way (Serafín, 2018); (Serafín, 2023)? After all, what sticks best in the mind is what everyone tries out and personally verifies (Baylor & Ritchie, 2002).

From the school's perspective, the abstract nature of the field of electrical engineering places demands precisely on the design of educational programmes, on the relevant chapters of textbooks and methodological manuals, but also on teaching aids (Stoffa & Šefara, 1999); (Thomas, 2016); (Sedlák & Štoll, 2002). Illustration plays a big role here. Introducing pupils to the basics of such a vast field as electrical engineering is not easy, especially if we bear in mind the short time currently allotted for this within the curriculum. The issue of didactic transformation is crucial in the teaching environment, as is the aforementioned demonstration. Of course, the teacher's approach is also indispensable, as discussed by David Heywood and Joan Parker in their book The Pedagogy of Physical Science (Heywood & Parker, 2012).

The issues of the concept of the curriculum, the approach to teaching, are connected with didactics, the theory of education, which deals with the forms, procedures and goals of teaching (Stuchlíková, Janík, Beneš, & et al. , 2015); (Janík, 2010); (Průcha, Walterová, & Mareš, 2013); (Serafín, 2023). In this context, we are talking about an educational process in which we introduce students to the secrets of electricity and the field of electrical engineering as a whole. As already mentioned here, part of this process is the question of the mediation of educational content, i.e. the selection of the curriculum and the specific didactic representation of the educational content by the teacher. However, the research in this area is rather fragmented, which, moreover, is confirmed by Marilyn Cochran-Smith and Ana Maria Villegas in their research report (Cochran-Smith & Villegas, 2014).

2 Concept of didactics of electrical engineering

If we want to conceptualize electrical engineering as a content of teaching, whether in the traditional sense or in an innovative way with elements of activating learning, we should first look at didactics from the perspective of the teacher's tool to conduct teaching.

Subject and subject didactics, along with general didactics, are among the pedagogical disciplines that describe and explain the processes of teaching and learning. General didactics establishes general patterns of teaching. If we focus general didactics on the teaching of specialised subjects, we move from the general position to the position of specific, i.e. subject or subject didactics (Stuchlíková, Janík, Beneš, & et al. , 2015); Janík, 2010; (Průcha, Walterová, & Mareš, 2013); (Serafín, 2023). The relationship between didactics and the relevant discipline is multi-layered and dynamic, and can therefore take different forms, but it is always necessary to balance the conditions of student learning and the disciplinary quality of teaching. The discipline of didactics is therefore a science that mediates the discipline towards the pupils2 .

Electrical engineering from the perspective of learning, didactics is the theory and practice of teaching and learning electrical subjects in relation to the education and formation of knowledge, skills, competences, attitudes and other dispositions and is therefore the sum of the didactics of individual electrical subjects, but is not the sum of these didactics. In general, terms the didactics of electrical engineering deals with:

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

On a special level, the didactics of electrical engineering discusses:

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

If we characterize the didactics of electrical engineering subjects as a science, then the didactics of electrical engineering can be understood as an interdisciplinary, independent boundary discipline that didactically processes the knowledge of electrical engineering and integrates it with the knowledge of social sciences in the didactic system of electrical engineering subjects (Serafín, 2023).

2.1 Electrical engineering as a subject of teaching

The relationship between didactics and electrical engineering science is very close. First of all, because the didactic transformation of the curriculum and the subject-matter expert content are based on the science. When examining the relationship between didactics and electrical engineering, from which the subject of teaching (for example, electrical engineering) is based, it is necessary to realize that didactics does not examine the laws of a specialized science, but the laws of the process of teaching, and therefore the process of learning about electricity, electrical engineering (Serafín, 2023).

For the successful implementation of teaching, of course, the teacher must have knowledge from a wide range of scientific disciplines and not only electrical engineering. Electrical engineering is very closely related to mathematical and natural science disciplines, and has its place in many engineering and technical applications of other sciences, but in the context of education in non-technical fields such as sociology, logic and others. Incidentally, electrical engineering is also an aggregate of many scientific fields in itself, many of which nowadays form separate disciplines (e.g. electronics, mechatronics, etc.). In summary, therefore, it can be said that the multidisciplinary of education does not avoid the specificity of electrical engineering, as is the case for other disciplines or fields. Slavík, Janík et al. also discuss this in their monograph on transdisciplinary didactics (Slavík, Janík, Najvar, & Knecht, 2017).

[2] Note: not all content in the field is conveyed, but those that appear to be useful from a teaching and learning perspective i.e. contribute to the development of knowledge, skills, competences, attitudes and other dispositions of pupils/students at a particular level and type of school are selected.

The socio-cultural changes underpinned by the information explosion and technological developments at the turn of the millennium brought with them, among other things, a certain cluelessness in the field of education, precisely in the context of the notion of didactic transformation. The ever-new insights that are emerging in terms of technology and the shifting knowledge of humanity are placing the disciplinary
and subject didactics under great pressure that has not yet been adequately mastered. There is thus no majority consensus on what the content of education should be and what methods and tools should be used to deliver it, which of course does not only apply to electrical engineering.

In the context of the increasing amount of information, there are significant changes in the conception of educational goals worldwide or innovations of the existing ones (Straková, 2013). In this context, there is talk of pedagogical constructivism, which has represented one of the dominant contemporary paradigms in didactics so far. The basic starting point is the learner constructing his/her knowledge on the basis of his/her own experiences. Many scientific publications have been written about constructivism as a theory of learning and much research has been carried out in which it has been shown that constructivist approaches can contribute to improving the state of learners' cognition and in the process of their learning in their understanding of basic knowledge and concepts (Naylor & Keogh, 1999), of which electrical engineering is full.

Although new approaches to science education have been developed just in the last few decades, thinking for example of inquiry-based learning (Dostál, 2015), scientific thinking continues to dominate mainstream school teaching, which is often dominated by fact-based teaching in the form of data and definitions. An unfortunate paradox of the current information and technology explosion is that the volume of almost ballast-like knowledge leads to information overload, resulting in further fragmentation and trivialization of knowledge and thinking.

3 New aspects in the concept of teaching electrical engineering in technical education

Electrical engineering is a concrete field with a content of laws that need to be known in order to reveal the essence of the field to the individual and to show even those areas that are hidden behind these laws to the ordinary observer. The question of experimentation, exploration, the search for creative solutions are tools to motivate in the process of learning, education. Moreover, in recent years they are supported by the development of digital literacy as one of the literacies needed for life in the 21st century.

The approach to the teaching of electrical engineering, as already mentioned here, requires a comprehensive concept combining the expertise of the "technician" and the pedagogical mastery of the "teacher". Curriculum design is then a very complex issue, which involves the search for possible ways of integrating diverse knowledge in conjunction with the effectiveness of its transmission. A significant role is played here by the already mentioned project, experimental, creative and research approach in connection with the didactic transformation of the content of the field (Kropáč & Kropáčová, 2006).

In the teaching of electrical engineering, basic scientific knowledge is presented, which teachers convey to pupils in such a form that pupils not only remember it, but also understand it and are able to work with it further. This approach is based on the re-shaping of educational content in the form of reducing the amount of scientific knowledge and returning it to a form in which this content is relatively easy for pupils to understand and is supported by project, experimental or even research activities in electrical engineering. In his work, Knecht (2007) proposed the so-called ideal model based on the development of concepts of didactic mediation of educational content with the definition of the roles of the different actors influencing the creation of educational content. This model illustrates a process that can be fully associated with electrical engineering (see Figure 1).

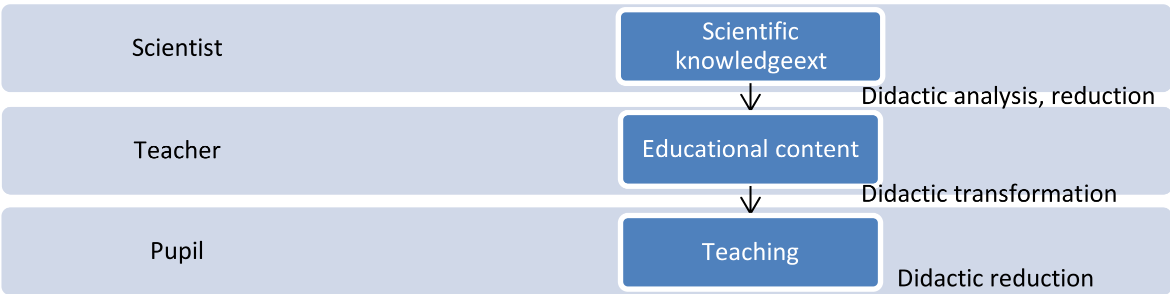

Fig. 1 Mediation of educational content (Source: Knecht, 2007).

3.1 Interactive learning in the context of electrical engineering

Interactive and multimedia teaching are nowadays concepts very well anchored in pedagogical theory and practice. One of its aims is to make today's teaching process more attractive and effective and to offer students new opportunities to actively engage in the acquisition of applicable knowledge and skills. The technological environment in which they are growing up offers many tools previously unthinkable in education and practice.

The development of technology, supported by the development of digital literacy, is leading us to view technology and technical literacy from a different angle than we have been used to, and today's generation is demonstrating this in their approach to learning and education in general. Demonstration is a fundamental perquisite that will always guide us as teachers in the teacher-student relationship.

Hrabal & Pavelková (Hrabal & Pavelková, 2010) in research focused on the popularity and difficulty of subjects from the perspectives of students and from the perspective of teachers. On the other hand, which subjects teachers think are popular with pupils and which are not because of their difficulty. The authors conclude that science subjects are the unpopular ones and are more difficult for pupils to master, whereas computer science appears to be the subject preferred by pupils. This statement, compared with the availability of ICT, leads to the conclusion that ICT-supported learning can be much more effective than previously assumed. This is also supported by the availability of these technologies in the home. Here, then, we can ask the question: Can the popularity of computer science and the availability of technological tools be used to support other, less popular educational subjects? And let us ask further: How can computer science be integrated into these subjects to make learning as effective as possible? One of the goals of the current changes in the Framework Educational Programmes in the Czech Republic is to integrate digital literacy into other areas of education, into educational subjects.

When we talk about interactive and multimedia teaching of electrical engineering, we associate this teaching mainly with interactive whiteboards. The interactive whiteboard, interactive and multimedia teaching model is now a frequently used model in modern teaching environments, provided that the appropriate multimedia textbooks or aids are available. Of course, working with a multimedia textbook using an interactive whiteboard is only one option. Significant in this matter are the various forms of animations, the use of videos and other multimedia where both students and teacher work in the same space connected by personal devices such as laptops, tablets or mobile phones.

Technology in general, and electrical engineering in particular, offers various possibilities for interactivity, which are just supported by contemporary technological possibilities. Here we can mention, of course, 3D modelling and the creation of animations and videos that can illustrate how certain devices are made or work. These videos, models and animations are very valuable tools in teaching because of their availability on the Internet for both students and teachers in teaching and self-study. At the same time, pupils can create them themselves in project-based learning under the guidance of the teacher, or the teacher can create them themselves. As an example, we present an application by students of the Department of Technical and Information Education of the Faculty of Education in Olomouc on the topic of electric motors (see Figure 2).

Another possibility of incorporating contemporary technologies designed primarily for entertainment is augmented or virtual reality. Especially augmented reality is one of the trends that have great potential for schools in the near future.

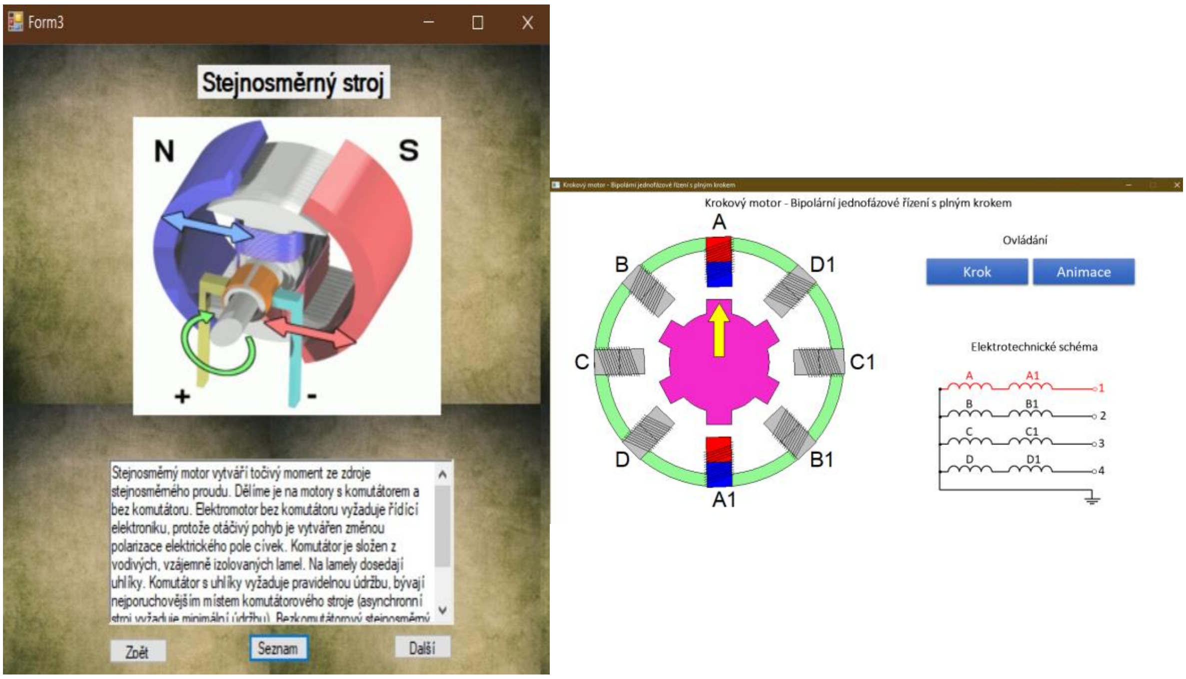

Fig. 2 Application on Electric Motors (Source: own processing)

According to Azuma (Azuma, 1997), augmented reality is only a part of virtual reality, although it allows the user to see the real world and the virtual elements placed in it in different layers. Other authors (Takemura, 1994) view augmented reality as a separate category of the technological and mobile industries, using some of the content used for virtual reality. The great advantage of augmented reality over virtual reality is that the device for displaying augmented reality can be smart mobile phones with a special application installed, tablets or laptops, but also special glasses (e.g. Google Glass, Epson Moverio BT-300) or helmets. However, the latter are already more expensive.

Fig. 3. Virtual switchboard with the real switchboard in the background (Source: https://www.vseoprumyslu.cz/digitalizace/virtualni-rozsirena-realita/digitalni-rozvadec-primo-na-stole-eplan-eview-free-nyni-s-ar-funkcemi.html)

The application of augmented reality in production practice is slowly becoming a common part of many companies. According to a survey conducted by the Association of Small and Medium Enterprises and Tradesmen of the Czech Republic, more than 30% of companies use virtualization technologies and more than 23% are considering using them.

Augmented reality makes it possible to create copies of real objects in a virtual environment and vice versa, to display virtual objects as if they were right in front of the observer. The basic idea is to map space using a camera. A mobile phone, tablet or goggles will get an idea of the environment they are in and then use 3D models and the appropriate software, a virtual production line or car can be seen, which can be virtually disassembled and examined for individual parts (see Figure 3) and a repair procedure can be designed for these.

The integration of virtualization tools into education has undoubtedly a future. Klement (Klement, 2020) states that "The use of virtualization technologies in education, or in school settings, is currently a relatively unexplored area. It is possible to find some works in the literature that deal with this issue in a partial way, but so far we are not aware of a review study that attempts to systematize the possibilities and ways of using this progressive technology in the conditions of the educational process".

3.2 On-line applications in electrical engineering

Simulation programs another of the tools that today open a wide field of possibilities for the analysis and simulation of processes in simple, but also very complex electrical circuits. However, their use in the teaching of electrical engineering has not been very frequent, even in university teaching. Electrical engineering is a discipline that is based on practical experimentation and there is no reason not to use the possibilities of various software or online applications and virtual reality tools.

As a result of historical developments that began in the 1950s and thanks to the power of contemporary computers, mobile phones and tablets, programs designed to simulate electrical circuits are now the standard for many so-called virtual laboratory tools. SPICE has become the standard for analogue simulation, while several software tools have been developed for digital simulation. Simulators with the "Mixed-Mode" attribute are capable of simulating circuits at both analog and digital levels (Banks, 1998).

From a teaching perspective, the analysis of electrical circuits can be characterized as a concrete procedure from the circuit model to obtaining a numerical result. Currently existing analysis methods can be divided into non-algorithmic, or heuristic, and algorithmic methods (Biolek, Výuka obecných metod analýzy lineárních obvodů, 1994). The former can be classified as procedures that the solver chooses based on his/her current and previous experience, thus it is a constructivist approach. The algorithmic method, on the other hand, defines a precise procedure - an algorithm, for example, in solving a circuit using the loop current method. Each of these methods performs a function in the solution: the non-algorithmic method forces the solver to think creatively in a technical way, while the algorithmic method provides a tool for the solution. Both approaches can be suitably combined in teaching.

Model analysis has its own objectives, inputs and outputs, method, form and means of implementation. The form of the analysis is mainly determined by the means of its implementation, i.e. a computer with appropriate software. In addition to computational and technical objectives, the analysis may have other objectives, for example, the teacher may assign pedagogical objectives in the form of practicing a particular analysis method or understanding a particular process in a circuit. Among the basic pedagogical objectives in the context of electrical circuit analysis we can see:

a) encouraging students to think creatively using the basic laws of electrical engineering (Ohm's law, Kirchhoff's laws) and principles (principle of superposition, equivalence, etc.). The analysis should contribute to a better understanding of the function of an electrical circuit. The pupil is thus actually exercising his "electrician's feeling" as to whether the distribution of voltages and currents is real or not, and how he can obtain further results from the partial results obtained so far;
b) mastering an effective tool, i.e., the algorithmic method of analysis, to solve electrical circuits; and
c) understanding the principles of circuit analysis methods implemented in commonly used simulation applications.

Computer simulation for the analysis of electrical circuits can nowadays be implemented using special software (typical representatives are TINA, MicroCap, Multisim, etc.) or using universal programs for mathematical and scientific calculations (MATLAB, MAPLE, etc.) (Biolek, 1999).

The advantages of using computer simulation in electrical engineering include:

1. the possibility to examine all parts of an electrical circuit without the need to incur the costs of its physical implementation. Also, the cost of eliminating the consequences of a bad decision is minimized by simulation;
2. it is often possible to incorporate changes in time and implement processes in an accelerated manner;

3. understanding of the causes of a given phenomenon in a real electrical circuit, which often cannot be explained except, for example, mathematically, but also those that cannot be captured in their entirety. The causes can thus be determined by examining in the process of reconstructing the events that took place in a given electrical circuit;
4. simulation can be used to solve, to design entirely new approaches, to implement new forms of electrical circuits and to simulate the consequences of these designs in real time;
5. simulation can be used to solve very complex systems that are not solvable or difficult to solve by analytical methods;
6. observation of the operation of the simulation model leads to a better understanding of the real electrical circuit.

On the other hand, the disadvantages of using simulation in electrical engineering include:

1. often the need for professional training to create simulations, especially in the use of relevant programs/applications;
2. the results of electrical circuit simulation can sometimes be interpreted only with great difficulty (random variables based on random inputs);
3. modelling and subsequent analysis can be time consuming;
4. electrical circuit simulation can be used inappropriately and sometimes not reflecting reality.

That an electrical circuit simulation may differ more or less from a real circuit is unfortunately a reality - the key is the inclusion or non-inclusion of all conditions and circumstances in the model that may affect the reality of the circuit. It is necessary not only to build the electrical circuit model, but also to include other conditions, i.e. to set the simulation parameters as accurately as possible. This circumstance depends on the capabilities of the program/application, what can and cannot be set.

Methods of analysis of electrical circuits should not only serve as tools for solving these circuits, but the teacher can also use their possibilities for explanatory purposes. However, it is necessary for the user to have at least a minimum theoretical background in order to use computer programs and applications for circuit simulation correctly, consisting of an understanding of concepts such as initial conditions, nonlinear and linear circuits, transient processes, steady state, etc. Thus, the approach to teaching in this concept has much different features from the classical laboratory teaching and combines different methods and procedures. Levert and Pierre (Levert & Pierre, 2000) offer a methodology - a general concept about modelling a virtual laboratory and using simulation models that should work in different configurations and on different platforms (Michael, 2001). Computer simulation, analysis of electrical circuits can be implemented in the school environment in two possible ways:

1. specialized software in the form of a computer program that the user installs on a computer, tablet or mobile phone or
2. online applications that allow simulations to be created directly on the Internet without the need to download the product to a computer.

Nowadays, one can encounter many programs and online applications that have different levels and usability both from the user's point of view and, above all, from the teacher's and student's point of view, i.e. from the point of view of the learning process in which they are or can be involved.

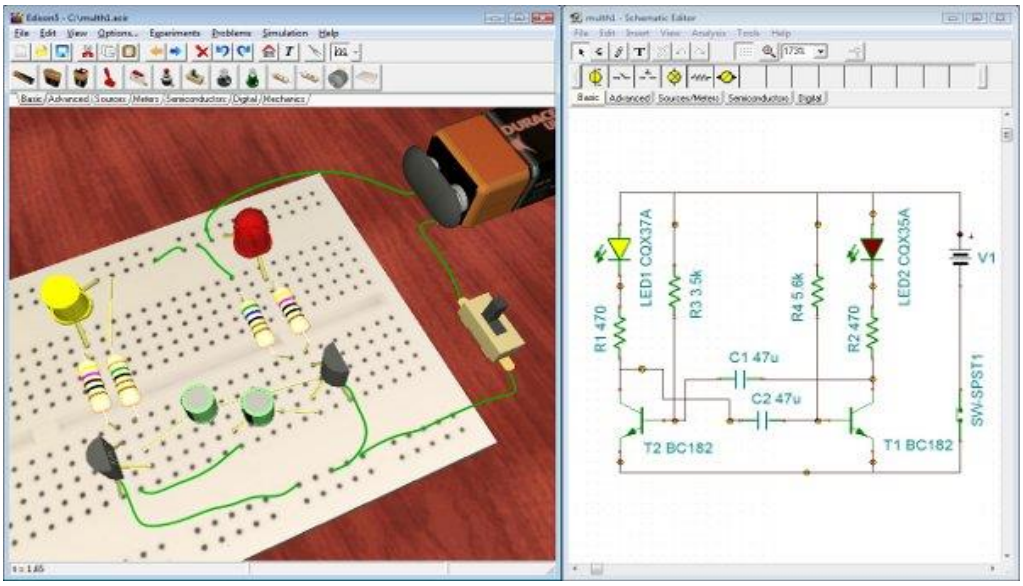

Fig. 4 Edison program (Source: own processing)

Figure 4 shows the Edison program from DesignSoft, which is based on the TINA platform. It is a program that needs to be installed on a computer. Edison can be considered as a good simulation tool that combines circuit diagram modelling with 3D visualisation of the individual components on the workbench. The program also offers experiments with problem problems and is distributed in Czech language.

Online simulation tools include Multisim Live (Figure 5), which allows the use of the same simulation technology as the Multisim program from National Instruments. The program provides an environment based on the SPICE standard. It includes analogue, digital and power electronics. In addition, the program allows the simulated circuits to be compared with real circuits, i.e. with real measurements in the Measurements Live environment using the NI ELVIS III oscilloscope. Due to the English-only version of the program, knowledge of professional English is also required.

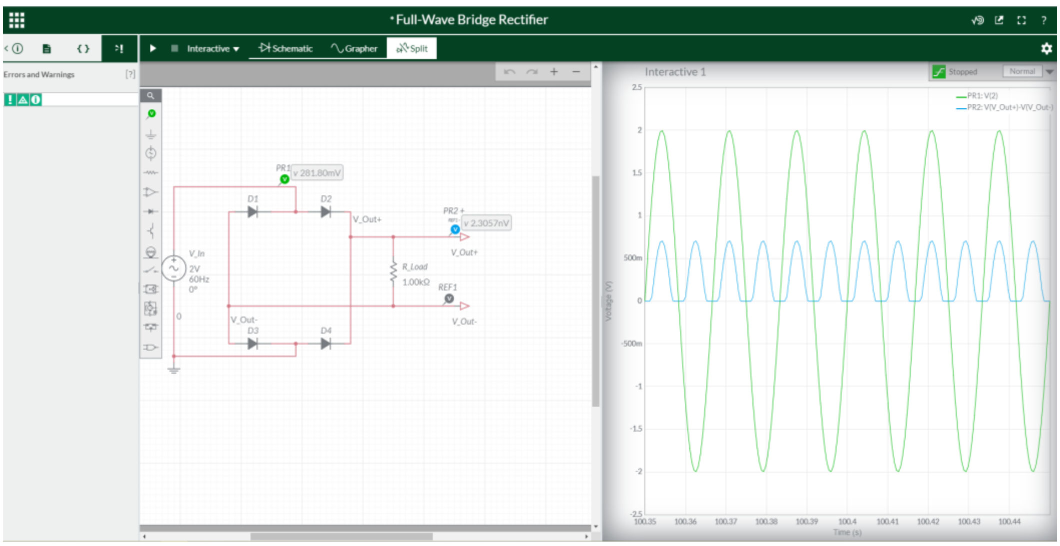

Fig. 5 Multisim Live application (Source: own processing)

4 Factors influencing the level of teachers' competences

For decades, many studies have found consistent results in terms of recognizing that teachers' competence in using digital technologies such as computers, mobile devices and the internet significantly influence their technical skills and other competencies towards modern technological tools for teaching leadership (Blotnicky, Franz-Odendaal, French, & et al., 2018); (Knecht, 2007). This was the reason for conducting a research investigation into the technical literacy of novice teachers in conjunction with digital literacy. The following research questions also informed the investigation:

1. What are the levels of technical and digital literacy with an emphasis on electrical engineering among beginning teachers?
2. What are the relationships between the variables of technological self-sufficiency, anxiety and uncertainty and the levels of technical and digital literacy with an emphasis on electrical engineering among pre-service teachers?

The research sample for this study was primary and secondary school teachers. A total of 360 teachers were interviewed in the study, of which 351 respondents' responses could be considered relevant to our study. The questionnaires included questions related to gender, number of years of teaching experience and questions dedicated to their technical competences in the field of electrical engineering, as well as digital competences related to the subject. These were graduates of teacher training courses with a focus on technical education, work activities, etc. Teachers, graduates of technical universities, were not contacted in this survey.

The first research question was measured by the mean of the respondents' answers with standard deviations. The second research question was analysed by correlation analysis of the relationship between self-confidence and anxiety and levels of technical competence with emphasis on electrical engineering. Subsequently, a t-test compared the level of competence between lower confidence/anxiety (below the mean) and higher confidence/anxiety (above the mean). This process allowed us to identify the factors influencing the level of technical competence in the selected sample of respondents by examining the relationships between the variables.

If we look at the means and standard deviations of the subgroups in the measurement of technical competence (see Table 1), we can interpret the results as showing that respondents differed the most in their answers, and therefore achieved the greatest variance in Networking or online communication about technology (mean 4. 57, variance 1. 38) and conversely, they achieved the lowest variance for Technical Skills in Electrical Engineering (mean 6. 25, variance 0. 85), with relatively low levels of variance in the categories of Technical Confidence in Electrical Engineering, Anxiety and Insecurity in relation to Electrical Engineering.

Category	Mean	Deviation
Technical skills in electrical engineering (TD)	6,25	0.85
Knowledge of the Internet world in relation to technology, information search, technical news (MGP)	5,59	1,29
Networking or online communication about technology (S)	4,57	1,38
Activity in technical creativity in relation to electrical engineering (AT)	2,46	1,23
Critical perspective on electrical engineering (KP)	3,72	1,19
Technical self-awareness in electrical engineering (TS)	5,44	0,93
Anxiety and uncertainty in relation to electrical engineering (UN)	3,06	0,86

Table 1. Averages and standard deviations of respondents' answers (Source: own elaboration)

The correlations between the two (Technical self-confidence in electrical engineering (TS) and Anxiety and uncertainty in relation to electrical engineering (UN)) and other groups (TD, MGP, S, AT and KP) are shown in Table 2. Pearson's correlation coefficient was chosen to determine these associations, which ranged from -0.28 to 0.66. There were then strong correlations between UN and S (0.53) as well as between UN and KP (0.54). It is also evident that TS is less strongly and negatively correlated with TD, MGP and S, but TS has no significant correlation with UN. In addition, no correlation was higher than 0.70.

	TD	MGP	S	AT	KP	TS	UN
TD	-	0,39	0,26	0,04	0,24	0,46	-0,28
MGP		-	0,33	0,21	0,45	0,47	-0,28
S			-	0,50	0,46	0,53	-0,17
AT				-	0,66	0,30	-0,02
KP					-	0,54	-0,04
TS						-	-0,27
UN							-
p < 0,01							

Table 2. Pearson correlations (Source: own elaboration)

Subsequently a t-test was performed between respondents who had a lower UN/TS ratio and those who had a higher UN/TS ratio (below and above the mean value). As expected, there were statistically significant differences for all categories with respondents who had higher UN than those who had lower UN (see Table 3). Respondents who had lower levels of uncertainty anxiety in relation to electrical engineering are also likely to have a better relationship with the subject, and probably prefer and do better with electricity in their teaching with their students. Similar to the results of the UN/TS correlation, it was found that for TD, MGP and S, there were significant differences for teachers with lower TS values than those with higher TS (see Table 4).

According to the responses and analyses conducted, it can be concluded in relation to the first question that novice teachers, equipped with technical skills and basic knowledge of electrical engineering, have confidence in their approach to teaching about electrical engineering and thus can probably inspire, guide their students, respond appropriately and interpret their questions, supported by digital tools. The second research question explored the interrelationships between the two factors and the other dimensions of technical or electrical literacy mentioned above, leading to a comparison of results between teachers with lower TS/UN and higher TS/UN. Technical Self-sufficiency was positively correlated with all criteria, while Technical Anxiety was negatively correlated with TD, MGP, and S. Technical Anxiety was not significantly correlated with AT and KP, indicating that teachers who are afraid of electrical engineering naturally resist activities in electrical creativity and their critical outlook towards electrical engineering in education is significant. This was particularly evident among primary school teachers.

	Lower UN		Higher UN		T
	Average	Deviation	Average	Deviation	
TD	5,92	0,99	6.54	0,56	-7,08
MGP	5,08	1.35	6,05	1,02	-7,51
S	3,94	1,25	5,13	1,24	-8.90
AT	2.10	1,04	2,79	1,30	-5,54
KP	3.16	1,02	4.22	1,09	-6,33

Table 3. T-test results between lower UN and higher UN (Source: own elaboration)

	Lower TS		Higher TS		T
	Average	Deviation	Average	Deviation	
TD	6,47	0,68	6,03	0,95	4,93
MGP	5,90	1,03	5,28	1,44	4,59
S	4,72	1,51	4,42	1,21	2.04
AT	2,44	1,28	2,49	1,18	-0,38
KP	3,74	1,31	3,70	1,06	0,30

Table 4: T-test results between lower TS and higher TS (Source: own elaboration)

Conclusion

The issues discussed here emphasize the field of electrical engineering as one of the partial and necessary components in the preparation of a future teacher in this field, whether he or she will be working in primary or secondary school. The level and scope of the preparation of such a teacher must include both the theoretical and practical areas related to this field, which the future teacher must understand, navigate and interpret in order to adequately transform the scientific knowledge of electrical engineering into the teaching process, but also to be able to engage and motivate his/her students to study.

The preparation of teachers of electrical engineering requires their quality preparation both professionally and didactically, which is very demanding both theoretically and practically. The demanding nature of the training is due not only to the fact that they must absorb knowledge of electrical engineering during their studies, but also of pedagogy, psychology and didactics, and that, in addition to theoretical knowledge, they must also master a certain practical aspect linked to manual activity and teaching skills - a certain mastery of the teacher.

The use of contemporary possibilities of technology gives stimuli for the implementation of the preparation of future teachers in higher education with other, not yet anchored techniques and methods, which, although they are still "in search" (also due to the fact that the development of technology is at speeds that have not been considered realistic so far) and are part of the discussions of expert panels at many levels, but at the same time these stimuli are an excellent preparation of future teachers for their own teaching practice. Now more than ever, we can say that the preparation of future teachers is beginning to correspond in real time with the demands and requirements placed on them in the reality of today's schools.

Reference

Azuma, R. T. (1997). Survey of Augmented Reality. *Department of Computer Science [online]. Presence: Teleoperators and Virtual Environments, 6*(4), pp. 355-385. Retrieved from http://www.cs.unc.edu/~azuma/ARpresence.pdf

Banks, J. (1998). Principles of Simulation. *Handbook of simulation: Principles, Methodology, Advances, Applications, and Practice.* (pp. 547-570). New York: John Wiley & Sons, Inc.

Baylor, A. L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers & Education, 39*(4), pp. 395-414.

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

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

Blotnicky, K. A., Franz-Odendaal, T., French, F., & et al. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education, 5*(1). Retrieved from https://doi.org/10.1186/s40594-018-0118-3

Cochran-Smith, M., & Villegas, A. M. (2014). Framing Teacher Preparation Research: An Overview of the Field. *Journal of Teacher Education, 66*(1), pp. 10-20.

Cook, P. N. (2004). *Introductory DC/AC Circuits. Pennsylvania State University.* Pearson/Prentice Hall. Pennsylvania State University.

Dostál, J. (2015). *Badatelsky orientovaná výuka: pojetí, podstata, význam a přínosy.* Olomouc: VUP.

Heywood, D., & Parker, J. (2012). *The Pedagogy of Physical Science Contemporary Trends and Issues in Science Education.* Netherlands: Springer.

Hrabal, V., & Pavelková, I. (2010). *Jaký jsem učitel.* Praha: Portál.

Janík, T. (2010). *Didaktika obecná a oborová: pokus o vymezení a systematizaci pojmů.* Retrieved from https://docplayer.cz/251433-Didaktika-obecna-a-oborova-pokus-o-vymezeni-a-systematizaci-pojmu-1.html

Klement, M. (2020). *Soubor cvičení do předmětu: Virtualizační technologie a jejich využití ve vzdělávání.* Olomouc: PdF UP. Retrieved from https://www.pdf.upol.cz/fileadmin/userdata/PdF/katedry/ktiv/Studijni_materialy/Klement/2020/VTV_2020_cviceni.pdf

Knecht, P. (2007). *Didaktická transformace aneb od didaktického zjednodušení k didaktické rekonstrukci.* Retrieved from ped.muni.cz: http://www.ped.muni.cz/weduresearch/publikace/0011.pdf

Kropáč, J., & Kropáčová, J. (2006). *Didaktická transformace pro technické předměty.* Olomouc: VUP.

Levert, C., & Pierre, S. (2000). Towards a Design Methodology for Distributed Virtual Laboratories. *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2000* (pp. 592-597). Chesapeake, VA: AACE.Retrieved.

Mayer, D. (1981). *Úvod do elektrických obvodů.* Praha: SNTL.

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

Naylor, S., & Keogh, B. (1999). Constructivism in Classroom: Theory into Practise. J. Sci. Teacher Edu. 10, 2 (1999), pp. 93–106. *Teacher Edu, 10*(2), 93-106.

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

Sedlák, B., & Štoll, M. (2002). *Elektřina a magnetismus.* Praha: Academia.

Serafín, Č. (2018). *Illustrative Electrical Engineering in the Primary School Curriculum.* Olomouc: VUP.

Serafín, Č. (2023). *Didaktika elektrotechniky. Rozvíjení kompetencí k řešení problémů.* Olomouc: VUP.

Slavík, J., Janík, T., Najvar, P., & Knecht, P. (2017). *Transdisciplinární didaktika : o učitelském sdílení znalostí a zvyšování kvality výuky napříč obory.* Brno: MU.

Stoffa, J., & Šefara, M. (1999). Naša vízia technickej výchovy tretieho tisícročia. *Modernizace výuky v technicky orientovaných oborech a předmětech* (pp. 10-17). Olomouc: VUP.

Straková, J. (2013). Jak dál v kurikulární reformě. *Pedagogická orientace., 23*(5), pp. 734-743.

Stuchlíková, I., Janík, T., Beneš, Z., & et al. . (2015). *Oborové didaktiky: vývoj, stav, perspektivy. Syntézy výzkumu vzdělávání. Brno: MU.* Brno: MU.

Takemura, H. (1994). Augmented Reality: A class of displays on the reality-virtuality continuum. *Ergonomics in teleoperation and control laboratory*.

Thomas, I. (2016). *Experiments with Electricity. .* Retrieved from www.converter.cz: http://www.converter.cz/fyzici/gilbert.htm.