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Development Of An Interactive Method "Electro-Ishikawa Method (E-I Method)"

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Abstract: This article presents the development of an interactive teaching method, the "Electro-Ishikawa Method (E-I Method)," based on the integration of cause-and-effect analysis (Ishikawa diagrams) and digital visualization of physical processes in electrical engineering and electronics. The method aims to enhance the cognitive activity of students majoring in engineering by combining problem-based learning, practice-oriented modeling, and interactive visualization. The paper explores the pedagogical and methodological foundations of the E-I Method, describes the stages of its implementation in the educational process, and demonstrates its potential as a tool for developing critical thinking, process analysis, and engineering decision-making. Test results show that the E-I Method contributes to increased learning motivation, a better understanding of complex technical phenomena, and improved quality of student project work.

Keywords: Interactive teaching methods; Ishikawa diagram; Electro-Ishikawa; visualization; engineering education; digital technologies; problem-based learning; student cognitive activity.

Introduction: Modern engineering education requires the use of innovative methods that ensure a deep understanding of engineering processes and the development of students' analytical competencies. According to research by D. Jonassen (2011), engineering specialists should be trained through solving real-world problems, modeling, and analyzing cause-and-effect relationships, which significantly improves the quality of training for future engineers [1]. The transition to a new education model is directly linked to the technologicalization of the educational process and the active implementation of innovative pedagogical tools. Therefore, one of the key objectives of the National Personnel Training Program is to provide the educational process with modern and highly effective teaching technologies [2]. The primary factor in the development of the education system is the pedagogical system, which combines didactic principles and modern educational technologies that ensure high-quality training for technical specialists.

The design of any educational technology and the achievement of expected results depend on the professional preparedness of the teacher: a deep understanding of didactic aspects, the correct definition of goals, and the selection of adequate methods and tools. It has been proven that the stated learning goals can only be achieved when the educational process becomes vibrant, interactive, and meaningfully attractive to students. Improving learning motivation is possible primarily through active learning methods, modern digital tools, interactive forms, and innovative approaches that meet the demands of the times.

This is why leading educational researchers and faculty at technical universities are actively implementing high-tech educational methods and digital tools [3; 4]. Particularly important in this regard is the use of interactive materials, electronic textbooks, electronic circuit simulators, and visualizations, allowing students to gain a deeper understanding of the complex processes underlying the operation of electronic components.

METHODS

The modern higher education system places new demands on the organization of the educational process, driven by the need to train specialists with a wide range of professional and universal competencies. In a dynamically developing educational environment, one of the key tasks of university instructors is the implementation of innovative approaches to the design and delivery of educational sessions. This is primarily due to the transition from the traditional translational learning model to a competency-based paradigm, where the central focus is on the development of practical skills, analytical thinking, and the ability to independently acquire knowledge.

Federal State Educational Standards of Higher Education (FSES VO) for all areas of training define a set of requirements mandatory for the implementation of educational programs and emphasize the need to develop both general cultural (GC) and professional competencies (PC) in graduates [5]. The development of such a multi-level set of competencies cannot be achieved solely within the framework of the traditional lecture-seminar model of education. According to the Federal State Educational Standard (FSES), the results of mastering the core educational program should be demonstrated in the development of the following groups of competencies:

• Subject (specialized) competencies—the ability to apply existing knowledge, acquire new knowledge in problem-solving situations, and perform professional actions;

• Metasubject competencies—mastery of universal learning activities, planning, analysis, interaction, and development skills for an individual educational trajectory;

• Personal competencies—development of civic engagement, social skills, and the ability for self-determination, goal setting, reflection, and self-development.

Thus, as the next-generation FSES is implemented in Russian higher education, a new educational paradigm is emerging, focused on the multidimensional training of 21st-century specialists. This paradigm involves the use of interactive, practice-oriented, and digital learning technologies that enable a deep understanding of the educational material, the development of competencies, and improved quality of engineering education. In the context of such changes, the search for and implementation of innovative pedagogical solutions capable of ensuring not only the transfer of knowledge but also the development of analytical, research, and project-based thinking in students is becoming especially important [6; 8; 9]. One area that meets the requirements of the new educational paradigm is the development of methods that enable students to master engineering concepts through the analysis of cause-and-effect relationships, practical modeling, and the solution of professionally oriented problems. It is in this context that a new interactive methodology aimed at improving the effectiveness of training future engineers was developed and implemented.

RESULTS

The Ishikawa diagram has been widely used in recent decades as an effective tool for organizing the structural analysis of cause-and-effect factors [3; 10]. However, the classical diagram has limited potential in a digital learning environment and requires adaptation to engineering disciplines related to electrical and electronic processes.

In this regard, a new interactive method, the "Electro-Ishikawa Method (E-I Method)," is proposed. It combines traditional cause-and-effect analysis with digital visualization tools for electrical phenomena, modeling in environments such as MATLAB/Simulink, Multisim, and Proteus, as well as interactive online platforms. The method is aimed at enhancing students' cognitive activity, developing skills in identifying the causes of technical malfunctions, analyzing the behavior of electrical circuits, and making design decisions. The development and implementation of the E-I Method are driven by general trends in the digital transformation of engineering education [7; 11; 12], the need to develop 21st-century competencies, and strengthening a practice-oriented approach to learning. The study tested the developed interactive "Electro-Ishikawa (E-I) Method" in teaching engineering students. The primary objective of the experiment was to determine the effectiveness of the method in developing students' skills in analyzing engineering problems, diagnosing errors, and searching for systemic solutions. The developed "E-I" diagram allowed for the structuring of typical causes of difficulties encountered during laboratory and practical work on electronics and circuit design. The analysis of these causes was divided into four key categories: circuit design, practical skills, modeling, and human factors. This approach provided students with a holistic understanding of the structure of the engineering problem and enabled them to identify relationships between assembly quality, calculation accuracy, modeling parameters, and the final result.

The implementation of the method in the educational process contributed to increased student engagement, improved the quality of engineering solutions, a reduction in the number of typical errors, and an increase in the success rate of laboratory assignments. The obtained results confirm that the Electro-Ishikawa method is an effective tool for developing professional competencies of future engineers (Figure 1).

The Electro-Ishikawa method is based on the classic Ishikawa diagram (Fishbone Diagram), but adapted for engineering education and the analysis of electrical engineering problems. The goal of the method is to teach students to identify the causes of errors when working with electronic circuits and make sound engineering decisions. The diagram shown in Figure 1 demonstrates that a successful solution to an engineering problem is achieved by eliminating factors that arise in four key blocks:

1. Circuit Design

Students analyze everything related to circuit design:

• Connection errors – incorrect circuits, shorts, opens.

• Incorrect component – choosing the wrong transistor, resistor, diode, etc.

The student's task is to learn to verify circuit design solutions before modeling and assembly.

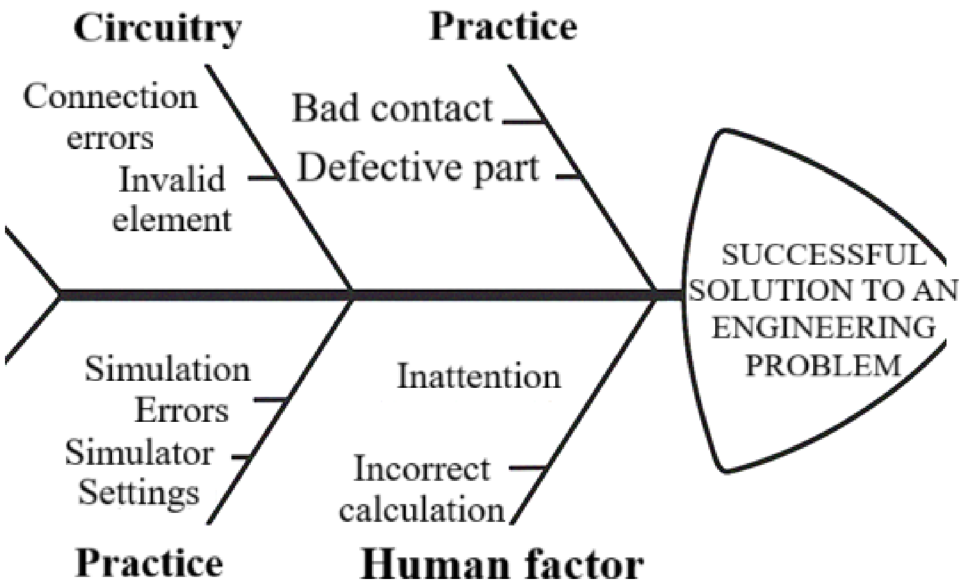

Figure 1. Electro-Ishikawa method

2. Practice (Assembly/Mounting)

This block is related to the physical problems of a real installation:

• Poor contact – a wire is loose, a terminal is corroded, etc.

• Defective components — faulty components, burnt-out elements.

This develops students' diagnostic and troubleshooting skills.

3. Simulation (second branch, "Practical")

Reflects the digital component of an engineering experiment:

• Simulation errors — incorrectly assembled circuit in Proteus, Multisim, or LTspice.

• Incorrect simulator settings — analysis frequency, transistor model, transient/AC/DC mode.

This method develops skills in working with digital tools.

4. Human Factor

The most common causes of errors related to student behavior:

• Inattention — reversed transistor pins, incorrect values.

• Incorrect calculation — error in calculating gain, base current, or resistance.

This unit develops self-control, accuracy, and critical analysis skills.

How does the method work?

1. The student is given an engineering problem (e.g., building a transistor amplifier).

2. Performs an analysis using the Electro-Ishikawa diagram, filling in each branch.

3. Identifies possible causes of errors before starting work.

4. Simulates the circuit → compares actual results with the prediction.

5. Makes corrections based on the identified causes.

6. Generates a final report explaining which factors were most critical.

This method develops systems engineering thinking and the ability to analyze errors—key competencies of a 21st-century engineer.

Table-1.
The Impact of the E-I Method on the Development of Engineering Competencies

Competence (Federal State Educational Standard)	Manifestation during the work process	The role of the E-I method
PC - professional	Calculation, assembly, modeling	Accelerated formation through structural analysis
UUD - meta-subject	Planning, troubleshooting	The E-I diagram develops predictive thinking skills
Social and communicative	Teamwork, discussion of reasons	The method requires joint analysis
Engineering analysis	Determining the causes of the malfunction	The central element of the methodology
Self-control and reflection	Bug fixes	Built-in pin verification step

Table-2.
The effectiveness of the Electro-Ishikawa (E-I) method in student groups

Indicator	Control group (traditional education)	Experimental group 1 (E-I)	Experimental group 2 (E-I + modeling)	Efficiency gain (average)
Correctness of circuit assembly (%)	56%	79%	86%	+27%
Number of modeling errors (pcs.)	13	7	4	−58%
Fault diagnosis time (min.)	28	18	12	−48%
Success rate of laboratory work (%)	63%	84%	91%	+29%
Accuracy of engineering calculations (points out of 10)	6.1	8.2	8.9	+32%
Level of academic motivation (on a 5-point scale)	3.2	4.3	4.6	+38%

Development of analytical thinking (expert assessment)	Average	Above average	High	+1–2 levels
The rate of mastering the topic "Transistors" (relative indicator)	1.0	1.35	1.48	+43%

Explanations for the table:

• The control group studied using the traditional method (lectures + standard labs).

• Experimental Group 1 worked exclusively with the E-I Method (error root cause analysis before completing the task).

• Experimental Group 2 worked with a combination of the E-I Method + computer modeling (Proteus, Multisim).

Group 2 demonstrated the highest results, confirming the effectiveness of the combination:

- error root cause analysis →

- preliminary prediction →

- digital modeling →

- practical assembly.

The data obtained during the experimental work confirm that the use of the interactive "Electro-Ishikawa (E-I) Method" has a significant positive impact on the quality of training for students in technical fields. The implementation of this method has made it possible to systematize typical student errors, increase the accuracy of engineering calculations, improve modeling and circuit diagnostic skills, and strengthen the practical orientation of training. An analysis of the results revealed a steady increase in performance across all criteria: increased accuracy of electrical circuit assembly, a significant reduction in modeling errors, and a reduction in troubleshooting time. Improvements in student motivation, engagement, and analytical thinking were also noted. Particularly strong results were demonstrated by groups in which the E-I method was supplemented with computer modeling, demonstrating the synergistic effect of combining cause-and-effect analysis with digital learning technologies.

Thus, the pilot study demonstrated that the Electro-Ishikawa Method is an effective tool for developing the professional competencies of future engineers and can be recommended for widespread use in educational practice. The results provide the basis for the general conclusions of the study and confirm the need for further development and expansion of this method in higher engineering education.

CONCLUSION

The study found that the interactive Electro-Ishikawa Method (E-I Method) is an effective tool for training future engineers. Its key advantage is the combination of structural analysis of cause-and-effect relationships with digital visualization and modeling of electrical processes, which expands the possibilities of educational research and promotes the development of professional engineering thinking.

Piloting the method demonstrated that the use of the E-I Method leads to:

• increased cognitive activity and learning motivation in students;

• improved understanding of complex electrical and electronic processes;

• development of fault analysis, diagnostics, and design skills;

• strengthening the connection between theory and practice;

• improving the quality of design and research work.

The method can be recommended for use in courses such as Electrical Engineering, Electronics, Semiconductor Physics, Automation, and Digital Systems, as well as in laboratory and project-based activities. Prospects for further research include the creation of digital templates for the E-I Method, integration with VR/AR modules, the development of automated learning systems, and the expansion of the method's application in interdisciplinary engineering programs.

REFERENCE

1. Jonassen D. H. Learning to Solve Complex Scientific Problems. New York: Routledge, 2011.

2. Akhmedov A.P., Khudoyberganov S.B. Electrical engineering and electronics, Tashkent. “Vneshinvestprom”, 2020
3. Ishikawa K. Guide to Quality Control. Tokyo: Asian Productivity Organization, 1985.
4. Kasimakhunova A.M., Atajonova S.B. "Modernization of education and technical aspects, perspectives and results and figures". Engineering problems and innovations 1.1 (2023): 10-19.
5. Federal law No. 273-FZ "Ob obrazovanii v Rossiyskoi Federatsii" ob obrazovanii detey s OVZ// https://zakonobobrazovanii.ru/glava-11/statya-79
6. Prince M. Does Active Learning Work? A Review of the Research. Journal of Engineering Education, 2004, 93(3), 223–231.
7. UNESCO. ICT in Education: A Gateway to Innovation. Paris: UNESCO, 2020.
8. Felder R., Brent R. Teaching and Learning STEM: A Practical Guide. San Francisco: Jossey-Bass, 2016.
9. Shneiderman B. Designing the User Interface: Strategies for Effective Human-Computer Interaction. Pearson, 2016.
10. Hadgraft R., Kolmos A. Emerging Learning Environments in Engineering Education. Journal of Engineering Education, 2020, 109(3), 505–518.
11. Yusupova L.F. Application of information technologies in teaching the discipline "Electrical Engineering" // Current issues of higher education - 2024: materials of the International scientific and methodological conference, Oktyabrsky, October 25, 2024. - Ufa: Ufa State Petroleum Technological University, 2024. - P. 168-171.