

OPPORTUNITIES AND CHALLENGES OF AI IN EDUCATION: A DIDACTIC PERSPECTIVE

Thomas N. Jambor

Didactics of Electrical Engineering and Computer Science, Leibniz University Hannover (Germany)

Abstract

The complexity inherent in lesson planning represents a significant challenge, particularly for novice teachers or those in training. A wide range of conditions must be taken into account, and highly interrelated decisions must be made. Furthermore, the individualization of learning processes for learners in learning groups of 25 or more participants represents a problem not only for novice teachers. For this reason, the present paper examines the question of how action-oriented teaching for vocational schools can be planned and evaluated with the help of generative AI tools. The technical focus is on the teaching of the fundamentals of electrical engineering, with a particular emphasis on addressing and, if necessary, correcting learners' preconceptions.

Keywords: *Constructivist didactics of electrical engineering (cDoEE), fundamentals of electrical engineering, preconceptions, learning plan.*

1. Introduction

Machine learning and artificial intelligence have permeated all facets of human life and are now an integral part of daily life in educational institutions at all levels. In the domain of education, a number of advantages emerge for learners and teachers, thereby facilitating more efficient learning and teaching processes. With a focus on pedagogical practices, artificial intelligence (AI) can facilitate the individualized planning of lessons and the creation of learning materials for each learner. Furthermore, they can provide assistance to educators in the process of evaluating homework assignments and grading examination results. With regard to this aspect, however, the responsibility for the possible assessment of learners must remain with human teachers, even if there is certainly a temptation to shift this responsibility and the associated apparent objectivity of assessment. The present paper aims to answer the following research question:

*How might teaching in the field of electrical engineering fundamentals be arranged
with the assistance of AI tools from a subject didactics' perspective?*

In order to respond to this question, an initial presentation of theoretical background information will be made, with a focus on the author's teaching background and a selection of AI tools. The subsequent sections will elaborate on the three domains identified above in which AI tools can be utilized. It is not feasible to furnish a comprehensive response to the aforementioned query due to the intricacy and breadth of the subject matter. Instead, the objective of this paper is to contribute to the ongoing discourse on the appropriate and ethically acceptable utilization of AI tools.

2. Theoretical framework

The theoretical framework of this article is rooted in Constructivist Didactics of Electrical Engineering (cDoEE) (Jambor, 2022), a methodological approach that emphasizes the instruction of fundamentals of electrical engineering within the context of vocational schools. Consequently, the subject didactics is presented first. In the following section, an explanation will be provided regarding the selection of AI tools utilized in this article.

2.1. Constructivist didactics of electrical engineering (cDoEE)

The cDoEE is based on constructivist learning theory (Chuang, 2021). Consequently, the activation of learners constitutes a pivotal component within the framework of learning-teaching arrangements. This approach enables learners to construct their structures (knowledge and skills) in a self-regulated manner. The concept of action orientation, a mandatory component of German vocational education, fosters this self-regulated learning. Within the framework of cDoEE, this concept is described on the basis of six abstract characteristics, which include, for example, subject reference, practical relevance, and metacommunication. Due to the inherent abstract nature of the characteristics, it is not possible to design concrete learning-teaching arrangements directly. Consequently, ten determinants are derived from these characteristics, thereby enabling such design. Examples of such determinants include internal differentiation, action structure, and action product. The description of the individual characteristics and determining factors can be found in Jambor (2024) and Jambor (2025a).

Since the three aforementioned determinants are relevant to this article, they will be outlined briefly here. Internal differentiation addresses the understanding that learners can only construct internal structures if information is meaningful and can be linked to existing cognitive structures (connectivity). Therefore, it is important to analyze learners and adapt teaching activities to their individual needs and motivational situations. One way to increase motivation is to use practical action products (e.g., repairing a DVD player) as the focus of learning activities. Additionally, structuring the learning process by the action structure supports learners and makes it easier for them to deal with complex action products. This process is based on the six phases of complete action: informing, planning, deciding, executing, checking, and evaluating (Lindemann, 2002). The author of this article adds an additional phase. This phase is the problem definition phase, in which learners analyze the problem and establish a motivational foundation for subsequent phases.

The aforementioned connectivity of new information may be influenced by preconceptions. These are explanatory patterns generated by learners through previous learning processes. Sometimes, these preconceptions are based on special cases and generalized without sufficient reflection. In this case, they are no longer valid and lead to a false understanding of context. These preconceptions are then classified as unhelpful (Jambor, 2025b) or misconceptions (Daud et al., 2015). One example of such a preconception is a series connection consisting of a resistor, an LED, and another resistor. While most learners think the first resistor limits the current through the LED, a few believe the second resistor has no influence. This is because the second resistor is located behind the LED. This idea is, of course, incorrect and makes constructing new knowledge difficult.

2.2. Selection of AI tools

Teachers reach their limits when they have to supervise 25 or more learners in a teaching-learning arrangement, particularly with regard to the determinant of internal differentiation. Even in an action-oriented, student-active setting, it is only possible to a limited extent to respond to learners' individual needs. This also relates to preconceptions. Teachers must recognize learners' unhelpful preconceptions and support them in reducing these preconceptions through explicit tasks. These processes are highly individual. Using generative AI tools can increase the individualization of materials and media, so that the needs of learners are better met.

In this paper, two generative AI tools will be used: ChatGPT 5.2 and Gemini 3 Flash. These tools will be referenced without their version names below. ChatGPT is used for this study because it is widely popular among learners and teachers. Gemini has already proven effective for subject-specific teaching purposes in previous studies, so it is also used here.

3. Use of generative AI tools

Both AI tools are provided with a brief description of fictional first-year “electronics technicians for devices and systems” (“Elektroniker für Geräte und Systeme”) students. Learning Field 1, “Analyzing Electrical Engineering Systems and Testing Functions,” is specified as the curriculum requirement because it focuses on the fundamentals of electrical engineering. Additionally, the individual competencies and content that should be the focus of the learning situation are specified for the AI tools. It is also specified that the entire learning situation should include 14 teaching hours and focus primarily on preconceptions. Since the author's research focuses on future teachers, this is included in the prompt for the AI tool.

3.1. Lesson plans

Since this article focuses on designing concepts for teaching rather than formal lesson plans, the formal criteria in (Jambor, 2025c) are not used here. Instead, the focus is on the subject-specific didactic aspects of the learning situations designed by AI tools. However, before these plans are created, the AI tools should suggest action products that are central to the learning situation.

The range of suggested action products by ChatGPT spans from a poster titled “This is how I imagine electricity,” to a comparison of series and parallel connections, as well as measurement instructions titled “Measuring correctly with a multimeter,” and a measurement report. In the author's view, the analysis of a simple lighting circuit and troubleshooting in a circuit diagram have the greatest motivational potential and relevance to the profession. Gemini makes similar suggestions; however, a concept map is a notable option because it allows learners to visualize their thoughts. A guide to troubleshooting and a real light control circuit are cited as action products with the greatest practical relevance. Overall, most of the suggestions can be effectively implemented in an action-oriented, learning-teaching arrangement.

For rough planning of the learning situation, the author selects a suggestion for the action product in both cases, using the real circuit. Although neither AI tool is directly oriented toward the complete action, a meaningful action structure can be identified. However, upon request, both AI tools can assign the action to the phases of the complete action. Gemini optimizes its own design and integrates project-based approaches. While ChatGPT focuses on individual lessons, Gemini plans double lessons; however, ChatGPT also combines individual lessons into blocks. ChatGPT switches between individual work, group work, and frontal teaching in terms of social form. While the variety of social forms in ChatGPT is useful, it introduces a certain amount of disruption when working on the task. Learners may lose focus on the collaborative creation of the action product if they change social forms too often. Currently, Gemini does not provide specific information about the social form within lessons, though this is not an issue at the planning stage. However, at the end of the rough planning process, Gemini offers the suggestion that students be divided into groups of nine or thirteen, which are then divided into groups of two or three. These groups should be heterogeneous in terms of performance and learning requirements. Since the author misunderstands the team approach, Gemini clarifies that the groups have no didactic significance.

According to the rough planning, both AI tools must plan a lesson in greater detail. The author selected a lesson from both drafts that offer opportunities to deal with preconceptions. ChatGPT employs a combination of frontal teaching and group work at this stage. The task, which consists of two circuits, is presented on the board and subsequently addressed in groups using worksheets. The results of these exercises are subsequently documented on the board. It is noteworthy that ChatGPT has indicated that experiments will be conducted in the subsequent lesson. According to the Gemini approach, which is designed to facilitate double lessons, the educational session is initiated with a deliberate provocation. From the author's perspective, this approach is intended to stimulate the students' interest and motivate them to work on the problem. Subsequently, the students engage in a series of experiments, the outcomes of which are subsequently summarized in a frontal setting. Based on their observations, the students perform calculations (group work, frontal teaching), so that knowledge transfer is ensured. The two lesson plans demonstrate an evident commitment to addressing preconceptions through both theoretical and practical approaches. This is a particularly useful approach within the framework of constructivist learning theory. In this particular instance, the author posits that Gemini's methodology is more efficacious, as it confronts learners with authentic, real-world problems that address their existing preconceptions. This methodological approach creates cognitive conflicts, compelling learners to introspect and engage in self-reflection, particularly regarding their existing preconceptions. Nevertheless, this analysis does not imply that ChatGPT's approach is ineffective. The formulation of assumptions and subsequent confirmation or falsification of these assumptions through theoretical exercises can also be regarded as a valuable activity. This is particularly true in the context of subsequent practical exercise. With regard to the target group (vocational school students), this approach is less suitable.

In addition to the process of lesson planning, both AI tools are tasked with the identification of potential comprehension issues and the development of courses of action for the teacher. ChatGPT's primary focus is on preconceptions and the issue of associating circuit diagrams with real circuits. The range of suggested options includes a positive error culture (allowing errors and viewing them as learning opportunities), practical experiments, and teacher-student dialogues (e.g., “Where do you measure the voltage?” “Why?”). Another option is to follow the current paths with a finger and reflect on the results. Gemini also systematizes suggestions based on possible preconceptions. The proposed methodologies encompass the utilization of a water flow model, an analogy to a supermarket checkout, and a role-playing scenario in which students adopt the roles of “pump,” “electrons,” “resistance,” and “measuring master.” It can be posited that Gemini's suggestions exhibit a degree of “creativity”. Moreover, the approaches proposed by ChatGPT and Gemini can be regarded as didactically useful and implementable in a vocational

school setting. In particular, the implementation of role-playing as a pedagogical method requires adaptation to the target group and a systematic introduction. Finally, it is imperative to underscore the potential risks associated with the utilization of analogies, as many preconceptions are rooted in the water flow model or similar analogies.

3.2. Teaching materials

As delineated in Section 3.1, the lesson planning process includes a request for AI tools to generate several teaching materials. The primary focus at this stage is on the planning of lessons, which were developed in detail. ChatGPT generates a board draft (possible result of class activities) and a worksheet. The board draft offers a useful comparison of series and parallel connections. In addition to addressing the configuration of the circuits and the behavior of current and voltage, the draft includes a discussion of the consequences of lamp failure and the relative brightness of the lamps. The final point may be slightly misleading. According to ChatGPT, the lamps should be dimmer in a series connection and equally bright in a parallel connection. This may foster the preconception that lamps in a series connection become darker as they are positioned further away from the positive pole. At this point, the intervention of a teacher is necessary. The ChatGPT worksheet comprises a combination of open-ended and multiple-choice questions. For the multiple-choice questions, learners are required to provide written justifications for their selected response. In the worksheet, learners engage with the content that has been summarized on the board. Furthermore, the worksheet contains a task that requires learners to apply their knowledge, thereby facilitating the transition from learning objectives at a low taxonomy level to learning objectives at a higher taxonomy level (Bloom et al., 1964).

Initially, Gemini offers a comparable board draft, but it does not exhibit the problematic representation of brightness. Furthermore, the electrical engineering relationships are presented in the form of mathematical formulas. The necessity of the mathematical description of the relationships becomes evident in the Gemini worksheet, as calculations for series and parallel connections are performed here. Two resistors ($R_1=200$ ohms, $R_2=300$ ohms) are used as examples in this analysis. It is imperative to underscore that the "commercially available" values from the E24 series are particularly relevant in the context of vocational education. In addition to the calculations, a "pre-concept check" question is included, which requires a more profound understanding of the subject matter among the learners. This is a reasonable and comprehensible perspective, although it should be noted that only a single such question is present in this instance. Furthermore, an expert bonus question is included, providing a mixed circuit for lower-performing learners and a simulation task for higher-performing learners. This is not the only example in the entire draft where Gemini provides internal differentiation without being requested to do so. Such tasks and hints can serve as a valuable support mechanism, particularly for novice teachers.

As previously delineated in Section 3.1, the two AI tools are tasked with estimating potential issues in teaching. In this context, they are instructed to create an additional worksheet to assist in dealing with two problems selected by the author. ChatGPT generates two worksheets that employ mnemonics to address preconceptions (e.g., "There are no branches in a series connection. The current is therefore constant in all points"). Furthermore, learners are requested to perform measurements and visualize current paths. The results of these measurements are reflected using the worksheet. According to the recommendation provided by ChatGPT, the worksheet can be made available to learners before, during, or after the experiment. From a didactic perspective, these measures can be regarded as useful and effective. Gemini employs analogies once more in this context, aligning with the recommendation made by ChatGPT that measurements be taken. Notwithstanding the problem of analogies potentially reinforcing preconceptions, this approach is beneficial for learners in their first year of training. As the analogies are supplemented by empirical measurements on real circuits, this risk is reduced.

3.3. Assessment of student results

In the context of evaluating student performance, automated assessment of single-choice and multiple-choice tasks is particularly straightforward. A notable disadvantage of this approach is that it exclusively evaluates learning objectives at low taxonomy levels. The evaluation of calculation results, wherein the sole focus is on the result itself, does not impose significant demands on the tools. However, given the absence of direct information regarding the learners' skills, a more thorough examination of the calculation process is necessary. This assertion extends to the evaluation of open-ended inquiries and the learners' approach, thereby rendering the utilization of AI tools indispensable for the automation of assessments, whether in their entirety or in part.

Savytska et al., for instance, demonstrate the feasibility of automated physical calculation evaluation through the integration of AI tools (Savytska et al., 2025). In addition, Chan and Lee have observed that reflective texts that emphasize one's own approach and thus a more profound process-oriented understanding are also favorably evaluated by AI tools. In this case, artificial intelligence has been shown

to demonstrate a higher degree of consistency in its evaluation process when compared to that of human evaluators. Additionally, it has been observed that AI exhibits a certain bias that favors linguistic clarity and the structuring of reflection (Chan and Lee, 2025). This bias is not always imperceptible in human evaluators. Consequently, the utilization of AI can be regarded as technically appropriate. The fundamental issue is rooted in the legal and ethical domains. Presently, the author is unaware of any legal framework that would permit the exclusive evaluation of student performance in Germany using exclusively AI. Nevertheless, it is feasible to provide teachers with assistance in their assessment. Moreover, data protection regulations must be considered, as highly sensitive learner data is made accessible to the AI system. In addition to the legal aspects, when deciding for or against the use of AI, it is important to consider the extent to which responsibility for assessment remains with human teachers and is not shifted to the machine support unit.

4. Conclusion and outlook

In addressing the research question, it can be concluded that the use of AI tools in the domain of teaching planning is a viable and effective approach. The examined examples demonstrated adherence to the concept of action orientation, consideration of preconceptions, methodological diversity, and adequate assessment of potential problems in teaching implementation. Gemini demonstrates subject-specific “creativity” in the methodological design and use of analogies to explain electrical engineering fundamentals. A similar positive assessment can be given to the teaching materials that were created. These resources are well structured and facilitate explicit engagement with preconceptions. Concurrently, it is imperative to acknowledge the necessity of critically evaluating the outputs of AI tools. This is because not all methodological decisions are meaningful in their entirety and, above all, appropriate for the target group. Moreover, the implementation of these proposed strategies has the capacity to engender novel preconceptions or to reinforce existing ones, thereby necessitating corrective intervention by the teacher. A similar degree of skepticism must be applied when evaluating student results, as it is not the technical aspects but the didactic, ethical, and legal ones of the evaluation that must always be questioned.

Future work will concentrate on the use of supplementary AI tools, the stability of the generated results in terms of quality, the consideration of specific preconceptions, and their systematization.

References

- Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1964). *Taxonomy of educational objectives* (Vol. 2). New York: Longmans, Green.
- Chan, C., Lee, K. (2025). Who Grades More Consistently? Exploring AI vs. Human Teachers in the Assessment of Reflective Writing. *AI-Enhanced Learning*, 1(1), 203-228.
- Chuang, S. (2021). The applications of constructivist learning theory and social learning theory on adult continuous development. *Performance Improvement*, 60(3), 6-14.
- Daud, N. S. N., Karim, M. M. A., Hassan, S. W. N. W., & Rahman, N. A. (2015). Misconception and difficulties in introductory physics among high school and university students: An overview in mechanics. *EDUCATUM - Journal of Science, Mathematics and Technology*, 2(1), 34-47.
- Jambor, T. N. (2022). *Konstruktivistische Fachdidaktik der Elektrotechnik* (Postdoctoral thesis, Munich, Germany, Dr. Hut).
- Jambor, T. N. (2024). The Use of Simulation Tools to Reduce Unhelpful Preconceptions in Electrical Engineering Education. *EDULearn 2024 Proceedings of the 16th International Conference on Education and New Learning Technologies* (pp. 2997-3007). doi: 10.21125/edulearn.2024.0798
- Jambor, T. N. (2025a). Hybrid Action-Oriented Learning and Teaching: A Transformative Approach to Vocational Education. *END 2025* (Vol. 02, pp. 33-37), Lisbon, Portugal.
- Jambor, T. N. (2025b). Action-Oriented Teaching and AI-Optimizing Educational Process in Electrical Engineering. *INTED2025 Proceedings* (pp. 1072-1081).
- Jambor, T. N. (2025c). Potential Role of AI Tools in the Development of Lesson Plans for Vocational Teachers. *iCERI2025 Proceedings* (pp. 4188-4196), Seville, Spain.
- Lindemann, H.-J. (2002). The principle of action-oriented learning. In GIZ (Hrsg.), *Linking German TVET with Anglo-Saxon CBET*, International Workshop. Weimar.
- Savytska, I., Bulgakova, O., Zbaravska, L., Rucins, A., Aboltins, A. et al. (2025). Application of Artificial Intelligence to Automatically Verify Student Calculations in Higher Education Institutions. *Environment Technology Resources - Proceedings of the International Scientific and Practical Conference* (Vol. 3, pp. 283-288).